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The Canadian Entomologist

Vol. XC Ottawa, Canada, November 1958 No. 11

New Species of *Iziphya* Nevsky (Homoptera: Aphididae)[1]

By W. R. Richards[2]

Insect Systematics and Biological Control Unit
Entomology Division, Ottawa, Canada

This paper includes descriptions of apterous viviparous females of five new species of *Iziphya*. In North America this sedge-infesting genus was formerly represented by a single species, *I. flabella* (Sanborn), which was described from a single apterous viviparous female (Sanborn, 1904, p. 37).

Key to North American Species of *Iziphya*

I. flabella (Sanborn) is included in the following key solely on the basis of Sanborn's descriptions and illustrations.

1. Tibiae each with a long, rod-shaped seta on dorsal surface near base (Figs. 9-11) 2
   Tibial setae near bases on dorsal surfaces strongly flabellate and not much longer than other tibial setae (Fig. 12) 4
2. Head and prothorax black, no distinct pale median vitta (Fig. 1) ..... *nigriceps* new species
   Head and prothorax with a distinct pale median vitta (Figs. 2-4) 3
3. Tarsi pale, not noticeably darker than tibiae; tergum of abdominal segment VII pigmented (Fig. 2) ..... *albipes* new species
   Tarsi fuscous, distinctly darker than tibiae; tergum of abdominal segment VII with irregular, isolated patches of pigment (Figs. 1, 3, 4) ..... *vittata* new species
4. Setae on dorsal surfaces of hind femora pointed or weakly blunt ..... *umbella* new species
   Hind femora each with at least one strongly flabellate seta 5
5. Head with a pale median vitta; hind femora each with one distinctly flabellate seta ..... *spenceri* new species
   Head black; femora with more than one distinctly flabellate seta (Sanborn, 1904, Fig. 95b) ..... *flabella* (Sanborn)

Iziphya nigriceps new species

Holotype.—Dorsal pigmentation essentially as in Fig. 1; no distinct pale median vitta on head or prothorax. Dorsum of head with a few, median, longitudinal, irregular rows of fine spicules, and irregular patches near eyes and along posterior margin; with strongly flabellate setae. Antennae about as long as body, blackish except basal two-thirds of third segments, which are yellowish; first and second segments each with a flabellate seta (Fig. 5); one primary sensorium near apex of each fifth segment, three near base of each unguis; secondary sensoria absent; first and second segments with fine, scattered spicules, other segments with closely set, encircling rows of sharp spicules, lengths of all antennal setae less than half basal diameters of third segments. Lengths of antennal segments: III, 0.55 mm.; IV, 0.275 mm.; V, 0.275 mm.; VI, 0.15 mm. + 0.25 mm. Rostrum reaching just beyond first coxae; apical segment with two setae in addition to usual three apical pairs. Dorsum of thorax with scattered, strongly flabellate setae; finely spiculose. Pro- and meso-thoracic femora black, each with pointed setae; metathoracic femora pale near base, each with one capitate and one strongly flabellate seta on dorsal surface; all femora with scattered fine spicules. Length of hind femur, 0.3 mm. Tibiae dark on basal third, each with two to four narrowly flabellate setae dorsally on basal pigmented portion, three or four slightly knobbed setae just distad of flabellate ones, pointed setae elsewhere; all tibiae with encircling rows of fine sharp spicules. Length of hind tibia, 0.5 mm. First tarsal segments pale, each with

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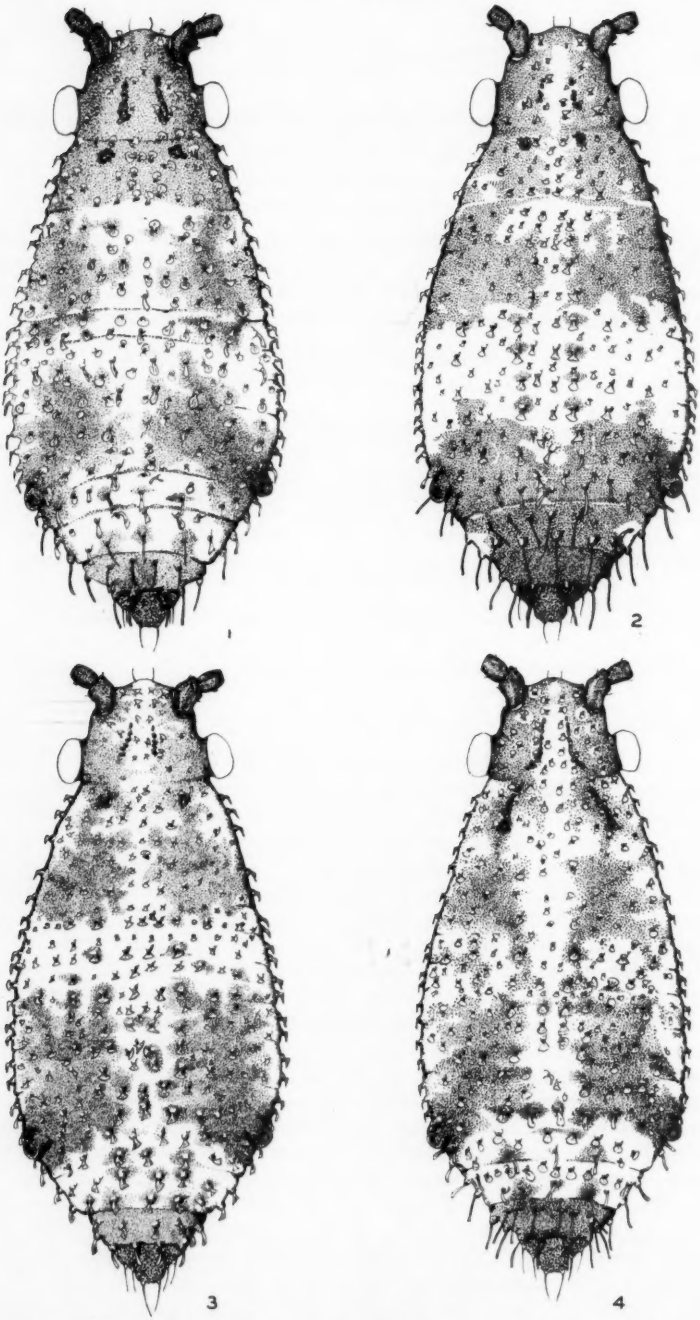


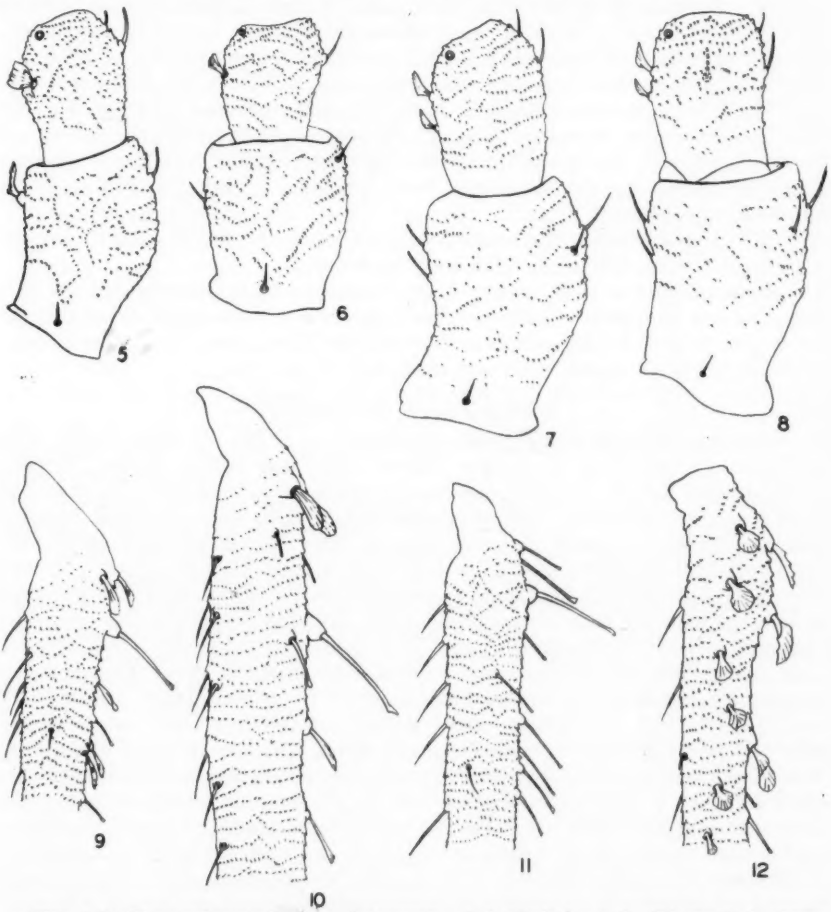
Figs. 1-4. *Iziphya* spp. Dorsal views of general pattern and chaetotaxy of: 1, *I. nigriceps;* 2, *I. albipes;* 3, *I. umbella;* 4, *I. vittata.*

five setae on ventral surface, the middle one being shortest and most slender; second tarsal segments dusky; all tarsal segments strongly spiculose. Dorsa of abdominal segments I-IV with strongly flabellate setae; segment VI with flabellate setae on anterior half, two to four rod-shaped ones on posterior half; segments VII-VIII with only rod-shaped setae (Fig. 5); segment VIII black, posterior margin not excised. Cornicles short, spiculose, normal for genus. Cauda black, knobbed. Anal plate black, deeply indented. Length 1.7 mm.

Collected at Highlands, North Carolina, Aug. 12, 1957 (W.R. Richards), on sedges. No. 6689 in Canadian National Collection.

Paratypes: Two apterous viviparous females. Data as for holotype.

Comments.—This species can be most readily recognized by the black head and prothorax. *I. flabella* (Sanborn) was described as having a black head, but, according to Sanborn (1904), *I. flabella* has flabellate setae on the dorsal surfaces of the tibiae, and the femora and on the posterior abdominal segments.



Figs. 5-8. First and second antennal segments. 5, *I. nigriceps;* 6, *I. albiceps;* 7, *I. vittata;* 8, *I. umbella.*

Figs. 9-12. Base of right hind tibia. 9, *I. nigriceps;* 10, *I. vittata;* 11, *I. albiceps,* 12, *I. umbella.*

***Iziphya albipes* new species**

Holotype.—Dorsal pigmentation essentially as in Fig. 2; a distinct, median, pale vitta that does not quite reach front of head. Dorsum of head spiculose; with strongly flabellate setae. Antennae about as long as body, blackish except basal halves of third segments, which are pale; second segments each with one flabellate seta; other segments with pointed setae that are shorter than half the basal diameters of third segments; one primary sensorium near apex of each fifth segment, three near base of each unguis; secondary sensoria absent; first and second segments with fine tubercles, other segments with encircling rows of fine spicules. Lengths of antennal segments: III, 0.45 mm.; IV, 0.25 mm.; V, 0.275 mm.; VI, 0.175 mm. - 0.275 mm. Rostrum reaching just beyond first coxae; apical segment with two setae in addition to usual three apical pairs. Dorsum of thorax with flabellate setae and scattered spicules. Femora black, with pointed setae only; and with fine, scattered spicules especially on ventral surfaces. Length of hind femur, 0.25 mm. Tibiae completely pale, lacking flabellate setae; with dorsal, blunt or distinctly capitate setae on basal halves; strongly spiculose. Length of hind tibia, 0.45 mm. First segments of hind tarsi each with five ventral setae; second segments pale. Dorsa of abdominal segments I-V with strongly flabellate setae; VI with flabellate setae on anterior half, rod-shaped or narrowly flabellate on posterior half; rod-shaped setae on segments VII-VIII and around cornicles; segments VII and VIII black dorsally. Cornicles normal for genus. Cauda black, knobbed. Anal plate black, deeply indented. Length 1.45 mm.

Collected at Marmora, Ontario, July 29, 1952 (E. H. N. Smith), in leaf mould. No. 6690 in Canadian National Collection.

Comments.—The chief distinguishing features of this species are the pale tarsi, absence of flabellate setae on femora and tibiae, black pigment on abdominal tergites VII and VIII, presence of rod-shaped setae around posterior margins of cornicles, short appendages, and small size.

***Iziphya vittata* new species**

Holotype.—Dorsal pigmentation essentially as in Fig. 4; with median vitta on head interrupted by a narrow, diffuse band just before vertex. Dorsum of head with a few, irregular, median longitudinal rows of fine spicules and some irregular, transverse rows near posterior margin; with scattered, strongly flabellate setae. Antennae about as long as body, blackish except basal two-thirds of third segments which are yellowish; second segments each with one or two strongly flabellate setae, other segments with pointed setae that are about as long as half the basal diameters of third segments; one primary sensorium near apex of each fifth segment, three near base of each unguis; secondary sensoria absent; first and second segments with fine tubercles, other segments with encircling rows of fine sharp spicules. Lengths of antennal segments: III, 0.65 mm.; IV, 0.35 mm.; V, 0.325 mm.; VI, 0.2 mm. + 0.3 mm. Rostrum extending slightly beyond first coxae; apical segment short, with two setae in addition to usual three apical pairs. Pro- and meso-thoracic femora blackish, lighter on basal half; each with pointed setae on dorsal surface; metathoracic femora narrowly pale near base, setae on dorsal surface pointed or slightly blunt or capitate; all femora finely spiculose, especially on ventral surfaces. Length of hind femur, 0.4 mm. Basal fourth of tibiae dark; each with two strongly flabellate setae near base, two to four narrowly flabellate setae; a few capitate setae distad of flabellate ones; all tibiae strongly spiculose. Length of hind tibia, 0.65 mm. Tarsi dusky, strongly spiculose, first segments each with five setae. Dorsa of abdominal segments VI and VII with narrowly flabellate or

rod-shaped setae; rod-shaped setae on VIII. Cornicles normal for genus. Cauda black, knobbed. Anal plate black, deeply indented. Length two mm.

Collected at Highlands, North Carolina, Aug. 21, 1957 (W. R. Richards), on sedges. No. 6691 in Canadian National Collection.

Paratypes: Five apterous viviparous females, collected at Hiawassee, Georgia (W. R. Richards), on sedges. No. 6691 in Canadian National Collection.

Comments.—This species is similar to *albipes*, from which it may be distinguished by its larger size and by having longer appendages, dusky instead of colorless tarsi, and a different chaetotaxy on hind femora.

Iziphya umbella new species

Holotype.—Dorsal pigmentation essentially as in Fig. 4; median pale vitta reaches front of head. Dorsum of head with a few, median, irregular, longitudinal rows of fine spicules; a few transverse rows near posterior margins; and with strongly flabellate setae. Antennae slightly longer than body, blackish, except basal half of third segments which are yellowish; first segment on one side with pointed setae, one flabellate seta on other side; second segments each with two strongly flabellate setae, other segments with pointed setae that are shorter than half the basal diameters of third segments; one primary sensorium near apex of each fifth segment, three near base of each unguis. Lengths of antennal segments: III, 0.525 mm.; IV, 0.3 mm.; V. 0.3 mm.; VI, 0.225 mm. + 0.3 mm. Rostrum short, reaching just beyond first coxae; with two setae in addition to usual three apical pairs. Dorsum of thorax with scattered, strongly flabellate setae; finely spiculose. Femora dark, slightly paler near base, no flabellate setae; but with scattered, fine spicules. Length of hind femur, 0.35 mm. Tibiae blackish on basal fourth, each with 10-13 strongly flabellate setae dorsally on basal half and two to four capitate setae just distad of flabellate ones; and with encircling rows of fine sharp spicules. Length of hind tibia, 0.6 mm. Tarsi dusky; each first segment with five ventral setae; strongly spiculose. Dorsa of abdominal segments I-VII with strongly flabellate setae; rod-shaped and narrowly flabellate setae on segment VIII; with fine, scattered spicules. Cornicles normal for genus. Cauda black, knobbed. Anal plate black, deeply indented. Length, 1.8 mm.

Collected at Normandale, Ontario, July 3, 1957 (W. R. Richards), on sedges. No. 6692 in Canadian National Collection.

Paratypes: 10 apterous viviparous females. Data as for holotype.

Comments.—This species is most readily distinguished by the relatively large number of flabellate setae on the tibiae, and the absence of rod-shaped setae on all the abdominal segments except segment VIII.

In the paratype series one specimen has a flabellate seta on one of the first antennal segments.

Iziphya spenceri new species

Holotype.— Dorsal pigmentation similar to that of *I. umbella*, but black patches on thorax and abdomen narrowly joined. Dorsum of head with some irregular, median, longitudinal rows of fine spicules, patches near eyes and near posterior margin; with strongly flabellate setae. Antennae shorter than body, blackish except third segments and ungues which are paler; second segments with two or three strongly flabellate setae, other segments with normal setae that are shorter than half the basal diameters of third segments; one primary sensorium near apex of each fifth segment, and three near base of each unguis; scattered spicules on first and second segments; other segments with encircling rows of fine, sharp spicules. Lengths of antennal segments: III, 0.45 mm.; IV,

0.35 mm.; V, 0.2 mm.; VI, 0.150 mm. + 0.2 mm. Rostrum short, reaching just beyond first coxae; apical segment with two setae in addition to usual three apical pairs. Dorsum of thorax with strongly flabellate setae, and with scattered fine spicules. Femora dark, slightly paler near bases; pro- and meso-thoracic femora with blunt setae dorsally, one seta strongly flabellate on dorsal surface of metathoracic femora; finely spiculose, especially on ventral surfaces. Length of hind femur, 0.35 mm. Tibiae blackish on basal halves; flabellate setae on dorsal surfaces of basal halves; capitate setae extending almost to apices on dorsal surfaces; with encircling rows of fine, sharp, spicules. Length of hind tibia, 0.55 mm. First tarsal segments pale, each with five ventral setae; second segments dusky; both segments with encircling rows of fine, sharp spicules. Dorsa of abdominal segments I-VII with strongly flabellate setae; setae on segment VIII narrowly flabellate or rod-shaped; with fine scattered spicules. Cornicles normal for genus. Cauda black, knobbed. Anal plate black, deeply indented. Length 1.8 mm.

Holotype.—Apterous viviparous female collected at Chilcotin, British Columbia, June 9, 1929 (G. J. Spencer). No. 6693 in Canadian National Collection.

Paratypes: Seven apterous viviparous females. Data same as holotype.

Comments.—This species is similar to *I. umbella*, from which it may be distinguished by the shorter appendages, the presence of a flabellate seta on dorsal surface of each hind femur; and the distinctly paler ungues in macerated material.

There is some variation in the extent of pigmentation and sometimes a distinct pale, median vitta extends from the front of the head to the anterior margin of abdominal segment VIII.

The species is named in honour of its collector, Professor G. J. Spencer, University of British Columbia.

Summary

The apterous viviparous of five new species of the sedge-infesting genus *Iziphya* from North America are described; four of these are found in Canada. A key to North American species is given. Previously *Iziphya* was represented by a single species in North America.

References

Borner, C. 1950. Neue europäische Blattlausarten. Selbtsverlag, Naumburg (Saale).

Gillette, C. P. 1909. Two little-known aphids on *Carex* sp. *Ent. News* 20: 119-121.

Gillette, C. P., and M. A. Palmer. 1931. Aphids of Colorado. Pt. I. *Ann. Ent. Soc. America* 25: 908.

Hille Ris Lambers, D. 1952. New Aphids from Sweden. *Opusc. Ent.* 17: 57-58.

Palmer, M. A. 1952. Aphids of the Rocky Mountain Region. *Thomas Say Foundation* Vol. V: 80-81.

Quednau, W. 1954. Monographie der mitteleuropäischen Callaphididae [Zierläuse (Homoptera, Aphidina)] unter besonderer Berücksichtigung des ersten Jugendstadiums. *Mitt. Zentanst. Heft* 78: 40.

Sanborn, C. A. 1904. Kansas Aphididae. *Kan. Univ. Sci. Bull.* 3: 37-38.

(Received July 2, 1958)

The Boxelder Twig Borer, *Proteoteras willingana* (Kearfott), (Lepidoptera: Olethreutidae)[1]

By L. O. T. Peterson[2]

Introduction

The boxelder twig borer, *Proteoteras willingana* (Kearfott) was described in 1904 from specimens reared by T. N. Willing, Regina, Assiniboia (now Saskatchewan), Canada, and temporarily placed in the genus *Proteopteryx* (Kearfott, 1904, 1905). In 1923 it was transferred to the genus *Proteoteras* (Heinrich, 1923). Early knowledge of life history and habits of this species is very fragmentary (de Gryse, 1924, 1925; Swaine, 1916, 1917; Washburn, 1910).

Boxelder or Manitoba maple (*Acer Negundo* L.), appears to be the only host of the boxelder twig borer. The important damage suffered is the destruction of the dormant leaf buds in the fall and early spring, and the burrowing of the succulent current twig growth in May and June causing spindle-shaped galls to form. These dry out and become woody, usually preventing further terminal growth of the infested twigs. Secondary branching results and if this growth is also destroyed, the affected trees become bushy and undesirable as shade trees.

The boxelder twig borer is widely distributed. In the United States, it has been reported from Minnesota (Washburn, 1910), the District of Columbia, Maryland, Ohio, Illinois, Missouri, Kansas, North Dakota (Heinrich, 1923). In Canada it probably occurs wherever its host tree is found. It is of greatest importance in the Prairie Provinces where boxelder is grown extensively in farm shelterbelts and as shade trees. The earliest report for the Prairie Provinces indicated severe and widespread damage in 1915 (Hewitt, 1917). Later accounts show that the borer occurred at Davidson, Saskatchewan, in 1925 and 1926. In 1929, 50 per cent of the new growth of boxelder in shelterbelts at Lethbridge, Magrath and Morrin, Alberta, was infested (Seamans, 1929), and the borer was numerous, generally distributed, and on the increase in Saskatchewan (Stewart, 1929). All boxelder in windbreaks at Morrin, Alberta, was severely infested in 1933 (Farstad, 1933). The borer occurred in almost all boxelder plantations examined throughout Manitoba, Saskatchewan, and Alberta, in 1938 and as many as 30 twigs on a single small stem were infested (Stewart, 1938).

More recent records on the abundance and distribution in the Prairie Provinces are provided through the Forest Insect Survey (Annual Reports, Forest Insect Survey, 1943 to 1956). The records indicate that the boxelder twig borer declined in abundance from its 1938 peak to 1946, increased again in 1947 and 1948, was at a low level from 1949 to 1954, and increased noticeably in 1955 and 1956. In 1956, the percentage of infested twigs from a limited number of sampling points was 13.4 for Southern Manitoba, 24.3 for Southern Saskatchewan and 9.7 for Central Saskatchewan.

Rearing Methods and Procedures

Boxelder twig borer moths were reared in large field cages set over small boxelder trees (Fig. 1) for data on the seasonal occurrence of the adults, and on egg deposition.

To investigate incubation, eclosion of the larvae, and the development and habits of the leaf-inhabiting larval instars, small potted boxelder trees (Fig. 2) were used. These were placed in large field cages containing moths, and exposed for 12-hour periods for egg deposition (Fig. 3). After exposure the

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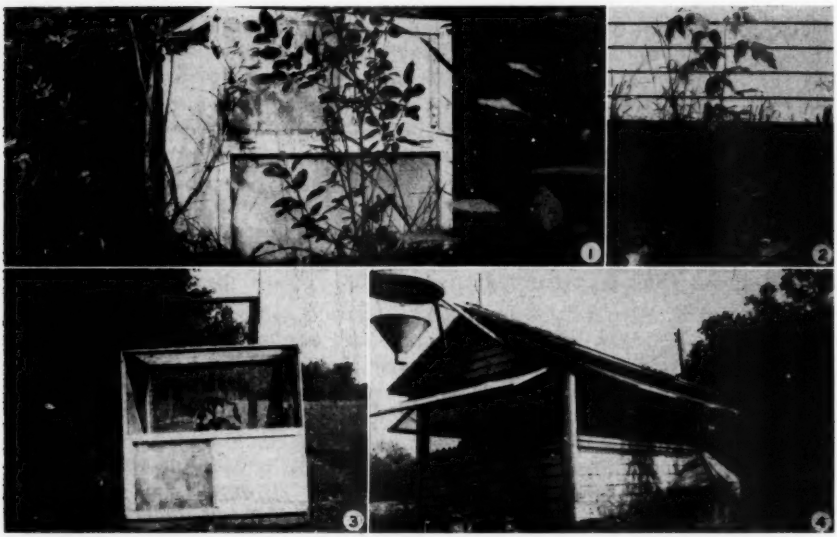


Figs. 1-4. Equipment used for rearing the boxelder twig borer. 1, Rearing cage. 2, Potted boxelder trees. 3, Potted trees in field cage for egg deposition. 4, Insectary.

potted trees were transferred to the insectary (Fig. 4) where daily observations on the eggs and larvae were made with the aid of a wide-field binocular microscope. This procedure did not excite the moths in the field cage, and it permitted continuous observations on the larval instars occurring on the leaves with minimum amount of disturbance. By combining direct and reflected lighting of low intensities during the examination, the activities of the larvae could be observed quite readily.

In the investigation of the development and habits of the bud- and twig-boring instars, random sampling of field populations was employed. This procedure permitted only one observation on each individual as it necessitated destroying the microhabitat provided by the bud or twig.

Head-capsule measurements were used in estimating the seasonal periods of the larval instars. Body size and coloration permitted the placing of borderline individuals.

Mature larvae were collected and reared individually in the field for data on the pupal stage.

Moths were reared outside in small cylindrical screen cages for data on longevity of adults.

Description of Stages

Egg Stage:

The egg (Fig. 5) of the boxelder twig borer is somewhat spherical to elliptical in shape, depending on its nearness to a leaf vein or the midrib, and has a flange-like margin. It is pearly-white, translucent, or may have a pale greenish tinge. The chorion is punctately sculptured, resulting in an irregular pattern of hollows and ridges. Measured eggs had a mean length of 0.53 mm. and a mean width of 0.39 mm. Variation in length ranged from 0.46 mm. to 0.58 mm. and in width, from 0.33 mm. to 0.50 mm.

TABLE I
Widths of head-capsules and head-casts of the boxelder twig borer

Larval Instar	Head-capsule measurements (in mm.)				Head-cast measurements (in mm.)			
	Number	Minimum	Maximum	Mean	Number	Minimum	Maximum	Mean
First	23	0.17	0.23	0.20	39	0.17	0.21	0.19
Second	49	0.25	0.30	0.27	26	0.25	0.30	0.27
Third	40	0.33	0.49	0.39	8	0.34	0.47	0.41
Fourth	66	0.29	0.45	0.36	45	0.33	0.54	0.44
Fifth	122	0.50	0.73	0.61				
Sixth	74	0.74	1.13	0.90				
Seventh	32	1.14	1.50	1.23				

Larval Stage:

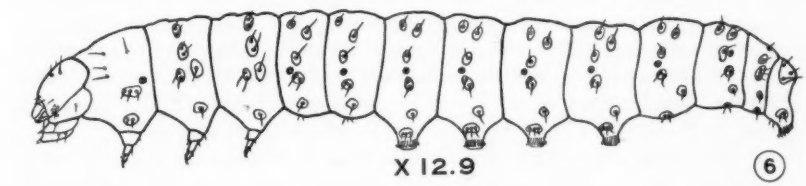
Seven larval instars were found. Data on head-capsule widths for all, and on head-cast widths for the first four instars, are given in Table I.

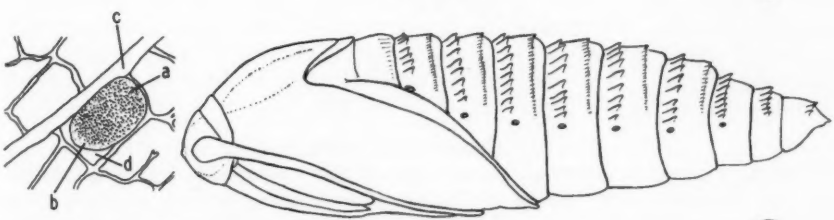
The newly-hatched larvae are yellowish-white, with light brown head capsules and eye spots. Before moulting they become greenish-yellow in colour, with dark brown head capsules and black eye spots.

Second-instar and early third-instar larvae differ from late first-instar larvae chiefly in size. In late third-instar larvae the pale yellow colour changes to a buff or golden-yellow, and in some individuals a reddish-brown tinge occurs.

Usually fourth-instar larvae are as small as, or smaller than their third-instar stage (Table I). In colour they are very similar to that of the late third-instar stage.

Fifth (Fig. 6), sixth, and seventh instars differ chiefly in size. Some fifth-instar larvae are as small as fourth-instar larvae. All are whitish-yellow in colour with brown or almost black head capsules. Raised cuticular areas bearing setae occurring above and below the abdominal spiracles are distinctive. These areas are oval in shape and greyish-black in colour. For fifth-instar larvae the





FIGS. 5-7. 5, Boxelder twig borer egg on leaflet, (a) punctate sculpturing, (b) flange-like margin, (c) vein of leaflet, (d) cell of leaflet. 6, Fifth-instar larva. 7. Pupa.

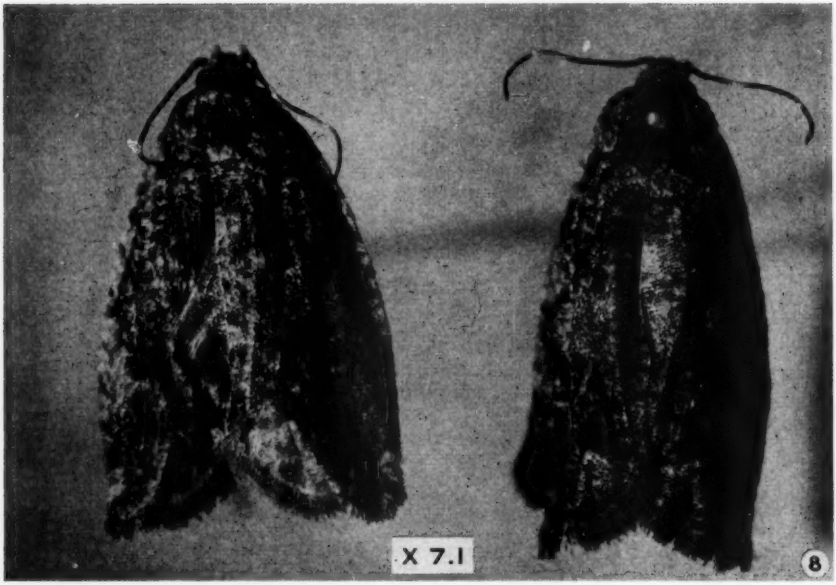


FIG. 8. Adult Female.

longer diameter did not exceed 0.08 mm.; for sixth-instar larvae they were approximately 0.10 mm. by 0.09.; for seventh-instar larvae, 0.27 mm. by 0.22 mm.

Pupal Stage:

The pupa (Fig. 7) is reddish-brown. A transverse row of large backward-projecting, widely-separated spines occurs near the anterior margin, on abdominal segments 2 to 7, and progressively nearer the posterior margin, on segments 8 to 10. This row extends laterally to the spiracles. A second transverse row of small close-spaced backward-projecting spines occurs near the posterior margin, on abdominal segments 2 to 7. This row does not extend laterally to the same degree as the anterior row and tends to fade out towards its extremities. Measurements of pupal length varied from 7.2 mm. to 10.8 mm.; the mean was 8.9 mm. Widths of the metathoracic segment varied from 2.1 mm. to 3.0 mm.; the average was 2.5 mm.

Adult Stage:

Kearfott (1904) described in detail the male and female moths. In general their ground-colour is white to pale brown-fuscous, and is overlaid with streaks, rings and clusters of yellowish-tan to black scales. The males possess a black sub-costal streak on the hind wing; the females, 4 clusters of raised scales on the forewing (Fig. 8). The alar expanse fluctuated from 15.0 mm. to 19.5 mm. for the males, and 17.0 mm. to 20.0 mm. for the females.

Life History and Habits

Fig. 9 gives the seasonal occurrence of the various developmental stages of the boxelder twig borer, at Indian Head, Saskatchewan, as shown by insectary and field rearings, and random field samples during 1936, 1937, and 1938.

Eggs were noted first on June 29, the latest hatching on August 2. Incubation in the insectary required from 9 to 14 days; the mean period was 11 days.

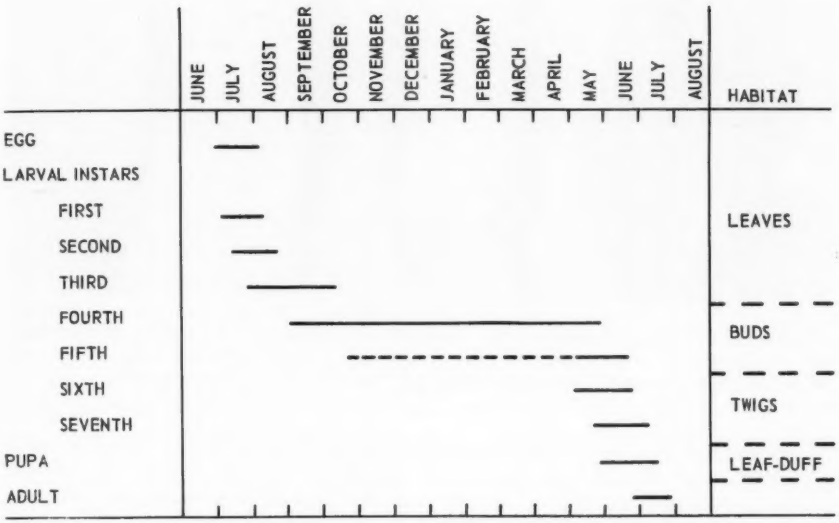


Fig. 9. Seasonal occurrence of the developmental stages of the boxelder twig borer.

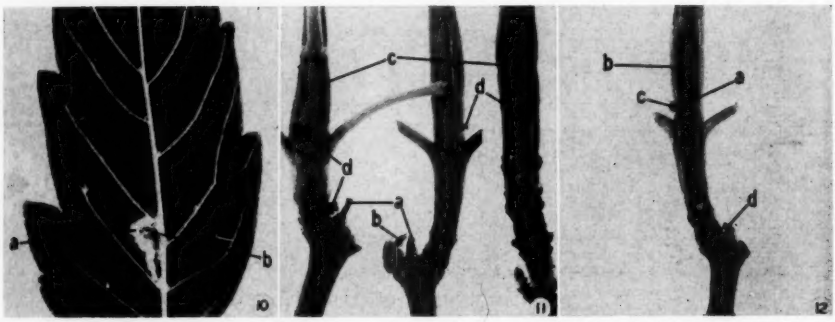
The eggs are usually deposited singly on the lower surface of the boxelder leaves, and are commonly placed adjacent to the midrib and the larger veins, quite often in the angle formed by their junction.

The unhatched larva is visible through the chorion before eclosion occurs. It is curved laterally with both extremities directed towards the same end of the egg.

The larval stage begins about the first week in July and extends over a period of 12 months. In all instars the larvae were noticeably solitary in habit. Wherever two occurred together one was always dead. This situation was most evident where several eggs had hatched on the same leaf.

Feeding begins soon after eclosion and in most cases occurs in the angle formed by the junction of a vein and the midrib, or along a vein or the midrib. Either surface of the leaf may be attacked though the larvae definitely prefer the lower. In feeding they remove the epidermis of one side and the mesophyll layers, causing the areas attacked to have a characteristically skeletonized appearance (Fig. 10(a)). About the time that feeding begins the larva commences to construct a web roof over a small portion of the leaf. Each feeding area is provided with such a shelter (Fig. 10(b)). Frass is incorporated into the outside surface to produce a rigid structure. Feeding occurs within this shelter until the enclosed leaf surface has been consumed. Skeletonizing then gradually extends beyond it but the larva returns to the shelter for its rest periods. The first-instar larva moults in this shelter. Having moulted the larva may move to another feeding area on the same leaflet or on an adjoining one and re-establish itself. From 4 to 9 days were spent in the first instar. The mean period was 6 days.

The second instar and early part of the third instar are also passed on the leaf. The activities associated with feeding and moulting are very similar to those of the first instar. The number of days spent in the second instar varied from 6 to 9 days for larvae reared in the insectary. The average was 8 days.



Figs. 10-12. 10, Boxelder leaflet, (a) skeletonized area, (b) larval shelter. 11, Infested boxelder twigs, (a) buds in which larvae wintered, (b) bud burrowed in spring, (c) enlarged burrowed twigs, (d) entries closed with frass plugs. 12, Sectioned boxelder twig, (a) burrow, (b) larva (almost mature), (c) frass plug, (d) bud in which larva wintered.

In general, the time spent on the leaf by third-instar larvae varied from 1 to 5 days. At the end of this period the larva moved to the base of the petiole and bored through it, or between the petiole and the stem, into the dormant leaf bud beneath to hollow out a chamber in which it hibernates (Figs. 11(a), 12(d)). This movement took place during the latter part of July and early August. In 1936, 21 per cent of the larvae had abandoned the leaves by July 26, and 65 per cent by August 8. From this time until activity is resumed in the spring very little feeding occurs. Before commencing to burrow into the dormant leaf bud, the larva constructed a web shelter very similar to that formed on the leaf blade. The upper and lateral edges are attached to the leaf petiole; the lower one is comparatively free. Frass produced in burrowing is used to close the outside entry and protrudes from it in the form of a plug. Occasionally the chamber formed may extend partly or wholly into the stem of the twig bearing the bud. Such instances are most frequent amongst larvae which penetrate the base of the petioles too far above or too far below the dormant buds. The larva covers the inner walls of the chamber sparsely with webbing and forms a denser mass of it across the opening of the passage-way to the outside, to complete the hibernation cell. Following this activity a quiescent period follows, which for most larvae, terminates with the third moult. The shortest recorded interval between entry into a bud and occurrence of the third moult was 22 days. More often this period is much longer, continuing to late September, and in some cases to late October or November. The winter is passed in a silken cocoon spun inside the hibernation cell. Usually the cocoon is formed in the fourth instar, but a few larvae form it in the third or fifth instar.

In a preceding section it was pointed out that most fourth-instar larvae were as small as, or smaller than their third-instar stage. Larvae which winter in the fifth instar also exhibit this phenomenon. This lack of growth appears to be the result of the long period spent in late summer and fall during which time very little food is taken and boring and web-spinning activities are great.

From late April to late May of the following spring, most of the larvae leave the hibernation cells before feeding or moulting and burrow into healthy buds on the same stems (Fig. 11(b)). Feeding occurs while burrowing. Having reached the centre of the bud, each larva hollows out another chamber. The passage-way to it, like that to the hibernation chamber, is closed with a

frass plug. After several days the larva moults to the fifth instar and soon afterwards vacates the cell and bores into the current tip growth of a twig where larval development is completed (Fig. 11(c)). During this latter period feeding increases and burrowing becomes more extensive so that chambers exceeding one inch in length are common in infested twigs (Fig. 12(a)). Entries to these chambers are closed with frass plugs (Figs. 11(d), 12(c)) except for short intervals. In late May and June, the mature larvae drop to the ground, spin up in cocoons in the leaf-mould, and pupate.

Not all larvae have these post-hibernation habits. Some which winter in terminal buds never vacate their hibernation cells until they are ready to pupate, except for short intervals when they emerge to feed on nearby buds. A few larvae moult twice in the first bud entered after vacating the hibernation cell. Still others hollow out 2 buds before burrowing into the current tip growth of the twigs.

Pupation began about May 29 and was concluded during the third week in July. The pupal period of individuals reared outside varied from 13 to 18 days; the average was 16 days. The mean pupal period for insectary rearings was 12 days.

The earliest recorded emergence of the adults was on June 27, the latest on July 19.

The sex ratio for moths which emerged in field cages was, females 56 per cent, males 44 per cent. Ninety per cent of the moths taken in a light trap during the period July 13 to July 23 were males.

Mating was not observed but egg laying occurred as early as 2 days after emergence of the adults.

The moths are most active in the evening and on warm cloudy days. They are quiescent on hot sunny days and on cool nights. With the sky overcast, the moths were very active at 86°F. and 26 per cent R.H.; quiescent but easily disturbed at 76°F. and 58 per cent R.H.; very quiescent at 66°F. and 56 per cent R.H. When inactive the moths prefer to rest on the trunks of the trees and in the leaf-duff rather than on the leaves. Most oviposition occurs during the evening. Ninety-eight per cent of the eggs laid during a four-day period were deposited between 8:00 p.m. and 8:00 a.m. Females dissected before egg laying had taken place yielded an average of 108 well-developed ova per female.

Longevity of the moths varied considerably. Maximum length of life in field cages was 15 days for males and 20 days for females. Only a few of more than 300 moths in rearing lived beyond July 22; none were alive after July 29.

Natural Mortality

Data on mortality from natural causes were obtained for the bud- and twig-boring phases of the larval stage. These data are presented for 'undetermined causes' and for 'parasites'. Predators appeared to be relatively unimportant. Occasionally a twig borer larva on the leaf or in a burrow was killed by another larva but was never eaten.

Undetermined Causes:

In 1936, 1.5 per cent of the hibernating larvae in samples taken at approximately weekly intervals from August 22 to October 10, and in a sample taken on November 17, were dead from unknown causes; by May 23, 1937, mortality had increased to 7.5 per cent. The figure for the corresponding period in 1937-38 was 9.0 per cent.

Mortality of larvae in buds and twigs burrowed in the spring was negligible. For the period May 25 to June 20, 1938, it was less than 1 per cent.

Parasites:

Parasites were the most effective, especially in the later larval instars. One tachinid was reared from the pupal stage of the borer. The parasite species obtained from reared host material, and the times of emergence, were as follows:

TACHINIDAE	
Anachaetopsis tortricis Coq.	July 7, 1937
BRACONIDAE	
Bassus sp.	June 22 to July 4, 1936
EULOPHIDAE	
Elachertus (*Hyssopus*) sp.	June 27, 1936
Euderus cushmani Cwfd.	May 21, 23, 1937
	May 12, 1938
ICHNEUMONIDAE	
Pristomerus ocellatus Cush.	July 23, 1935
	June 26 to July 4, 1936
	June 29, 1937
	July 5 to 15, 1938
Campoplex (prob.) *moderatus* Vier.	June 24 to July 4, 1936
Campoplex moderatus Vier.	June 29 to July 7, 1937
	July 1 to 15, 1938
Lissonota sp.	June 26, 28, 1936
Cremastus similis Cush.	July 2, 1938
Atrometus clavipes (Davis)	July 16, 1937
Ascogaster n. sp.	July 1, 2, 1938

In 1936 an estimated 30 per cent of the larvae in the buds and twigs were parasitized, of which 20 per cent were by *Campoplex* (prob.) *moderatus* Vier.

References

Annual Reports, 1943 to 1956, Forest Insect Survey, Can. Dept. of Agriculture.

de Gryse, J. J. 1924. Injurious Shade Tree Insects of the Canadian Prairies. Can. Dept. Agr. Ent. Br. Pam. 47: 18.

de Gryse, J. J. 1925. Injurious Shade Tree Insects of the Canadian Prairies. Can. Dept. Agr. Ent. Br. Pam. 47 Rev. Ed. 19.

Farstad, C. W. 1933. Forest and Shade Tree Insects, Can. Insect Pest Review 11: 58.

Heinrich, C. 1923. North American Moths of the Subfamily Eucosminae. U.S.N.M. Bull. 123: 167.

Hewitt, C. G. 1917. Report of the Dominion Entomologist for the Year Ending March 31, 1916: 41.

Kearfott, W. D. 1904. A New *Proteopteryx*. Can. Ent. 36: 306.

Kearfott, W. D. 1905. Assiniboia Micro-Lepidoptera, Collected by Mr. T. N. Willing. Can. Ent. 37: 89.

Seamans, H. L. 1929. Forest and Shade Tree Insects. Can. Insect Pest Review 6: 18.

Stewart, K. E. 1929. Forest and Shade Tree Insects. Can. Insect Pest Review 7: 45.

Stewart, K. E. 1938. Forest and Shade Tree Insects. Can. Insect Pest Review 16: 233.

Swaine, J. M. 1916. Injurious Shade Tree Insects of the Canadian Prairies. Agr. Gaz. Can. 3: 218.

Swaine, J. M. 1917. Shade Tree and Forest Insects of Manitoba. Agr. Gaz. Can. 4: 758.

Washburn, F. L. 1910. Thirteenth Report of the State Entomologist of Minnesota for the Years 1909 and 1910: 109.

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A New Nearctic Species of *Symballophthalmus* Becker (Diptera: Empididae)[1]

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The genus *Symballophthalmus* Becker, 1889 (= *Macroptera* Becker, 1889, preocc.), was erected for *Tachydromia dissimilis* Fallén (= *M. pictipes* Becker). This species, known from central and northern Europe, has been the only one definitely referred to the genus.

In 1954 and 1955, two male and two female specimens referable to this genus were collected in the vicinity of a spruce bog near Ottawa, Ontario, and five females were collected in Michigan during several years. These agree very well with the description of the type species except in the bristling of the front legs of the male and in details of the hypopygium.

The best recent diagnosis of *Symballophthalmus* is that by Melander (1927). The genus keys out to *Charadrodromia* Melander in Curran's (1934) Key to Families and Genera of North American Diptera, but differs in that the anal cell is present and the eyes contiguous on the front. It is most closely related to *Platypalpus* Macquart, differing most strikingly in the slender and only weakly bristled middle legs. Additional characters are as follows: Eyes broadly contiguous on the front, widely separated on the face; third antennal segment long-conical, equal in length to the arista; proboscis directed obliquely forward; palpus short and slender; legs slender, the fore tibia almost as thick as its femur, mid femur only slightly swollen and with weak ventral bristles, mid tibia without an apical process, hind femur elongate slender; wing long cuneate, basal cells long, slender, subequal.

Symballophthalmus masoni n.sp.

Figs. 3-6

Closely related to *S. dissimilis* (Figs. 1-2), but lacking the long flexor (posteroventral) hairs on the male front metatarsus, having more distinct mid femoral bristles, and the male hypopygium with cerci simple (not asymmetrical as in *dissimilis*), and with ventral lobes much larger.

The detailed description is as follows:

Length 2.0-2.5 mm. Head and thorax black, occiput lightly dusted, thorax glossy except for metanotum. Abdomen yellowish-brown, hypopygium black. Antennae and legs yellow; apical half of third antennal segment, arista, fore tibia, apices of hind femur and tibia, and all tarsi brownish. Wings clear, veins pale brown. Halteres pale yellow.

Head spherical; ocellar prominence very weak; eyes large, weakly sinuate on posterior margin, facets somewhat larger anteriorly. Occiput with weak pale hairs dorsally and ventrally. Ocellar bristles weak. Antenna with first joint partially fused to second, both small; third joint long-conical, longer than basal segments and equal in length to arista. Proboscis directed obliquely forward, weakly tapering, half as long as head height. Palpus minute, slender, with a fine apical hair.

Thorax without strong bristles; setulae brownish, slender, reclinate on anterior half, proclinate or erect on posterior half. Two rows of acrostichal setulae, four pairs of weak dorsocentrals, about six humerals, several weak an-

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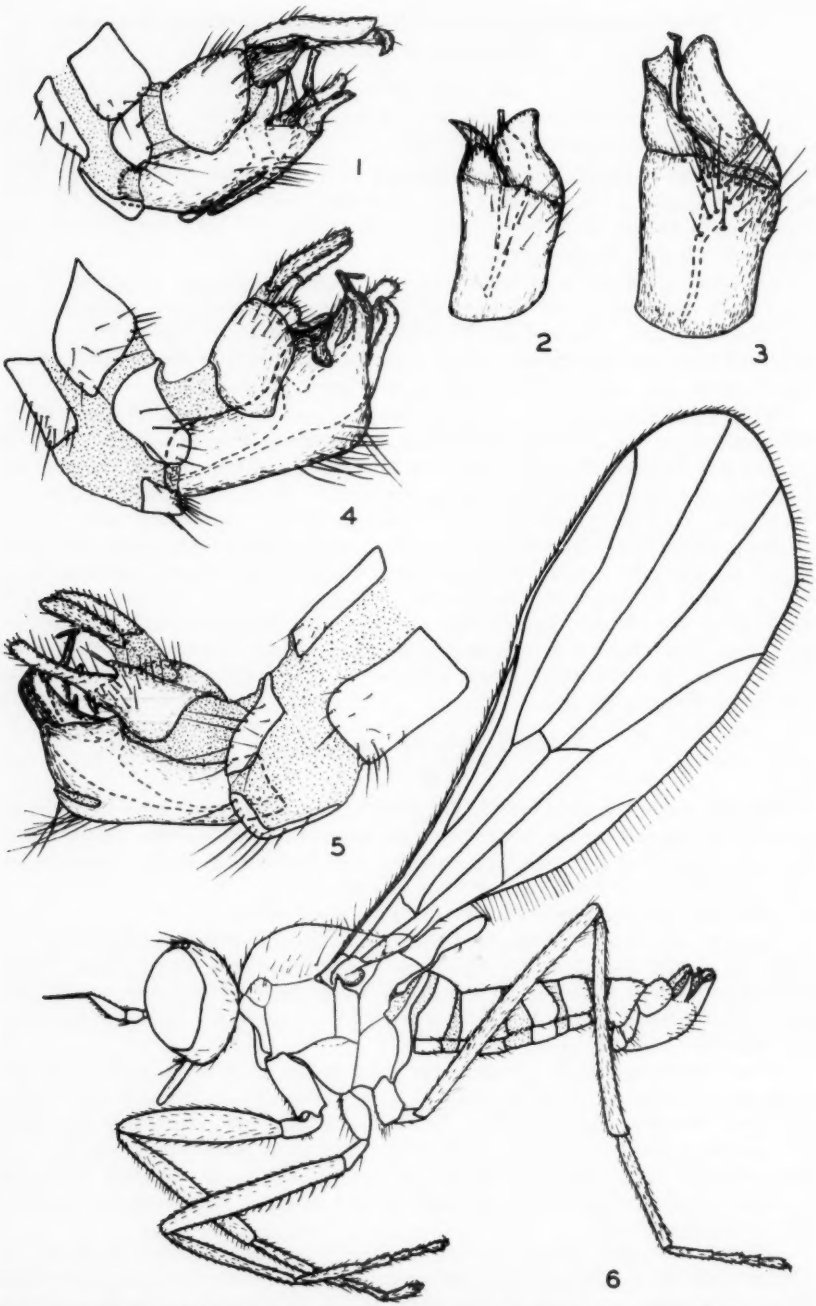

FIGS. 1-2. *Symballophthalmus dissimilis*, hypopygium: 1, lateral view; 2, ventral view.
Figs. 3-5. *S. masoni*, hypopygium: 3, ventral view; 4-5, lateral views.
Fig. 6. *S. masoni*, lateral view.

terior and one strong posterior notopleural, no strong prescutellar, but several short setulae near base of scutellum. Scutellum with two strong median and two weak lateral bristles. Pleura bare and glossy, the metapleuron pollinose. Knob of haltere elongate.

Wing long cuneate, basal cells long and subequal, posterior crossvein oblique, costa extending entirely around wing. Anal vein near wing margin, anal cell closed by a faint oblique crossvein.

Legs slender, without strong bristles except for an anteroventral and a posteroventral row on mid femur with bristles two-thirds as long as diameter of femur at base, decreasing evenly to setulae at apex. A few long hairs present ventrally at base of fore and hind femora and at apex of hind femur. Fore femur and fore tibia weakly swollen. Mid and hind legs long and slender, the tibiae four-fifths as long as their femora.

Abdomen weakly sclerotized, with only six visible segments besides the darkened terminal segments, all with sparse yellowish setulae. Female with an elongate ovipositor with slender cerci; male with a well-developed pollinose hypopygium (Figs. 3-5), processes glossy.

Holotype.— ♂, Mer Bleue, Blackburn, Ontario, 12.V.1954 (W. R. M. Mason), C.N.C. No. 6688.

Allotype.— ♀, same locality and collector, 27.VI.1955.

Paratypes.—1 ♂, same data as holotype; 1 ♀, same data as allotype; 5 ♀ ♀, Midland Co., Michigan (R. R. Dreisbach): 1 ♀, 1.VI.1934; 1 ♀, 3.VI.1941; 1 ♀, 15.VI.1950; 2 ♀ ♀, 14.VI.1952.

The species was compared with males and females of *S. dissimilis* from Dunoon, Scotland.

Summary

A new species of *Symballophthalmus* Becker, a genus new to North America, is described from the north-east. Figures are included to show the genitalic differences which separate it from the European and only other species of the genus. Relationships of the genus to other nearctic genera are discussed.

References

Becker, Th. 1889. Altes und Neues aus der Schweiz. Wien. Ent. Zeit. 8: 73-84.

Becker, Th. 1889. Berichtigung. Wien Ent. Zeit. 8: 285.

Curran, C. H. 1934. The families and genera of North America Diptera. Ballou Press, New York, N.Y. 512 pp.

Melander, A. L. 1927. Diptera. Family Empidae. Genera Insectorum, Fasc. 185. 434 pp.

(Received Sept. 22, 1958)

Development, Mortality from Starvation, and Oviposition of the Pale Western Cutworm, *Agrotis orthogonia* Morr. (Lepidoptera: Noctuidae), When Fed on Various Food Plants[1]

By L. A. Jacobson and P. E. Blakeley[2]
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When a crop has been destroyed by the pale western cutworm, *Agrotis orthogonia* Morr., one to two weeks may elapse before plants of the second seeding emerge. During this time the larvae may be starved or, at least, subjected to a suboptimum food supply. Frequently the second seeding may be of a different crop from the one that was destroyed.

A previous investigation (Jacobson, 1952) showed that mortality of the starved larvae varied directly with temperature and inversely with size of larvae. Seamans and McMillan (1935) reported that, when the larvae were fed various foods, differences were found in the rate of development and survival.

This is a report on the effect of feeding various foods on the rate of mortality when the larvae were starved in the fourth instar and, also, the effect on growth of the larvae and fecundity of the moths when these foods were fed throughout the larval period.

Methods

Larvae were reared in the laboratory as reported by Jacobson and Blakeley (1957). Newly hatched larvae, in groups of 25, were fed on sprouts of Marquis and Thatcher wheat, Exeter oats, and Compana barley. The fourth-instar larvae were placed singly in 15-x-60-mm. petri dishes. Four replicates of 15 larvae for each food were starved, and a similar number were fed for the remainder of the larval period.

Mortality in the starved series was recorded daily. In the series that were fed, dates of pupation and emergence, weight of pupae in milligrams at pupation, sex of moths, and numbers of eggs laid were recorded as they occurred for each of the food plants.

The experiments were conducted at 25°C. in a constant temperature room where the variation was less than one degree.

During starvation, moisture was added to the containers to maintain the relative humidity at approximately 50 per cent. This moisture level was less harmful than either a saturated or a dry atmosphere (Jacobson and Blakeley, 1957).

Various differences in response to food were analyzed by methods described by Cox (1954).

Replication for the data on oviposition was not possible because the moths emerged over a long period.

Results

Fig. 1 shows the cumulative mortalities of starved larvae after feeding on the various food plants. The mean numbers of days to death were 13.1, 12.7, 12.1, and 10.3 days for the larvae feeding on Marquis wheat, Thatcher wheat, Compana barley, and Exeter oats, respectively, the difference necessary for significance at the one per cent level being 1.85 days.

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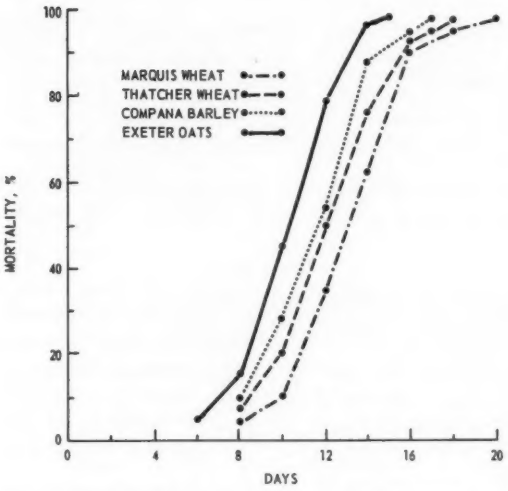

Fig. 1. Cumulative mortalities of larvae of *A. orthogonia* reared on sprouts of various grains and starved in the fourth instar.

TABLE I

Mean pupal weights (mg.) and durations (days) of various stages of *A. orthogonia* Morr. when the larvae were fed on various foods

Food plant	Pupal weight	Larval period	Pupal period	Hatch to emergence
Marquis wheat	283	45.7	22.0	67.8
Thatcher wheat	252	45.6	22.1	68.0
Compana barley	241	51.8	21.3	71.0
Exeter oats	169	52.7	19.6	73.7
Difference necessary for significance at 5% level	23	1.2	0.9	1.8
at 1% level	44	1.8	1.3	2.6

Table I shows that Exeter oats was inferior to the other plants as larval food. This is indicated by a lower pupal weight, a longer larval, and a shorter pupal period.

Weight of pupae indicated the nutritive value of the various foods. Mean weights of pupae in the replicates are associated with the mean duration of the larval period when fed throughout the larval period ($r = -.747$) and with the mean numbers of days to death when starved in the fourth instar ($r = +.799$).

The numbers of eggs laid by moths from larvae that were fed the various foods were:—

B & Z Library

	Marquis wheat	Thatcher wheat	Compana barley	Exeter oats
Number of females emerged	21	16	12	17
Mean number of eggs per female	111	155	79	35

These data show further that wheat as food was superior to barley or oats and, also, that weight of pupae (Table I) is associated with numbers of eggs laid ($r = +.644$).

Discussion

Differences in survival, size, and fecundity of various insects when fed on different food plants have been recognized (Painter, 1952; Pfadt, 1949). Other workers have found that cutworms respond differently to various foods. Lozina-Lozinskii (1954) showed that the vigour and numbers of the second generation of *Chloridea obsoleta* F. depended upon the nutritive condition of their native food plants. Differences in pupal weight and duration of development were found by Snyder (1954) when larvae of *Peridroma margaritosa* (Haw.) were fed various foods.

The investigations reported herein show that differences exist in the nutritive value of wheat, oats, and barley to the pale western cutworm. These differences are indicated by the mean number of days to death of starved fourth-instar larvae and by weight of pupae when the larvae were fed on the various foods. As the correlation between these criteria was significant, the period of survival of starved fourth-instar larvae may be used as an index of the nutritive value of various food plants or even of varieties of the same plant.

The growing of an unsuitable plant, such as Exeter oats, throughout an area may reduce the population by lowering the fecundity. When a field of wheat is destroyed by cutworms it is often reseeded to oats or barley as these crops mature more quickly. Hence, the larvae may be starved and some may die during the interval between destruction of the first seeding and emergence of the second, and the seeding of an inferior food plant may reduce the population further by delaying development and reducing the fecundity.

Summary

When sprouts of Marquis wheat, Thatcher wheat, Compana barley, and Exeter oats were fed to larvae of the pale western cutworm it was found that the wheat varieties were superior as food. Exeter oats was inferior to the others, starved fourth-instar larvae died more quickly, and when fed for the entire larval period the pupae weighed less, and the moths laid fewer eggs.

References

Cox, Constance E. 1954. Handbook on statistical methods. Canada Dept. Agr., Sci. Serv., Statistical Res. and Serv. Unit Processed Pub. 3. Revised.

Jacobson, L. A. 1952. Effects of starvation on larvae of the pale western cutworm, *Agrotis orthogonia* Morr. (Lepidoptera: Phalaenidae). *Can. J. Zool.* 30: 194-200.

Jacobson, L. A., and P. E. Blakeley. 1957. A method of rearing the pale western cutworm, *Agrotis orthogonia* Morr. (Lepidoptera: Phalaenidae), in the laboratory. *Canadian Ent.* 89: 87-89.

Jacobson, L. A., and P. E. Blakeley. 1957. Effects of moisture during starvation of larvae of the pale western cutworm, *Agrotis orthogonia* Morr. (Lepidoptera: Noctuidae). *Canadian Ent.* 89: 465-469.

Lozina-Lozinskii, L. K. 1954. The role of nutrition in the development of the cotton noctuid (*Chloridea obsoleta* Fabr.) (in Russian). *Trud. vscsoyus. Ent. obsch.* 44: 3-61. Cited in Rev. Appl. Ent., A, 44: 140, 1956.

Painter, R. H. 1952. The role of nutritional factors in host plant selection. *Trans. IX Int. Congr. Ent.* 2: 101-110.

Pfadt, R. E. 1949. Food plants as factors in the ecology of the lesser migratory grasshopper, *Melanoplus mexicanus* (Sauss). *Univ. Wyoming Agr. Expt. Sta. Bull.* No. 290.

Seamans, H. L., and E. McMillan. 1935. The effect of food plants on the development of the pale western cutworm (*Agrotis orthogonia* Morr.). *J. Econ. Ent.* 28: 421-425.

Snyder, K. D. 1954. The effect of temperature and food on the development of the variegated cutworm, *Peridroma margaritosa* Haw. (Order Lepidoptera, Family Noctuidae). *Ann Ent. Soc. Amer.* 47: 603-613.

(Received May 20, 1958)

Varietal Resistance of Seeded Onions to the Onion Maggot, *Hylemya antiqua* (Meig.) (Diptera: Anthomyiidae)[1]

By J. P. Perron[2], J. J. Jasmin[3], and J. Lafrance[2]

Investigations by Baker and Stewart (1928), Sleesman (1934), and Matthewman *et al.* (1953) on varietal resistance of seeded onions to the onion maggot, *Hylemya antiqua* (Meig.), gave no significant results, probably because they were made on small numbers of commercial varieties. This is a report on field and greenhouse tests from 1955 to 1957 on 44 varieties of *Allium* spp. grown from seed. The variety Early Yellow Globe was used as a standard of susceptibility to the onion maggot in all tests.

Materials and Methods

Field Tests.—Field tests were carried out at the Horticultural Organic Soil Substation, Ste. Clothilde de Chateauguay, in a decomposed muck soil fertilized annually with a 2-12-10 mixture at 1200 pounds per acre. Tests were made in 1955 and 1956 on 44 and 16 varieties, respectively, sown in single-row plots replicated three times. The rows were four feet long and 17 inches apart, and 120 seeds were sown in each. Nine varieties were tested further in 1956. Seven of these were again tested in 1957, the plots being replicated six times in a randomized block design. Each of these plots was ten feet long and had four rows 17 inches apart, and the seed was sown at three pounds per acre.

When most of the plants were three to six inches high, the infestation of the maggot was increased by releasing several hundred adults at weekly intervals between May 25 and June 15, approximately 2000 flies being released each year. The plots were in a field of nearly three acres surrounded by trees and shrubs, and the flies were released upwind of the plots to facilitate uniform dispersal over the plots. Records of maggot-killed plants were taken at least twice a week during June and once a week thereafter until harvest. The plants killed were clipped at ground level and the plants remaining at harvest were pulled out and examined for maggot injury.

Greenhouse Tests.—Greenhouse tests were conducted at the Science Service Laboratory, St. Jean, during the winter of 1956-1957. The temperature was kept between 60° and 80°F. and the relative humidity at approximately 85 per cent, and the air was circulated by a large electric fan. Seven varieties representing levels of resistance were selected out of previous field tests. An eighth of an ounce of seed was sown in muck soil in wooden flats, six by six by 24

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TABLE I

Mortalities of seedling onions from attack by the onion maggot, field tests 1955–57

Species and variety 1955	Total No. of Plants	Plant mortality %	Angular transformation	Species and variety 1956	Total No. of Plants	Plant mortality %	Angular transformation	Species and variety 1957	Total No. of Plants	Plant mortality %	Angular transformation
Allium fistulosum L.				*Allium fistulosum* L.				*Allium fistulosum* L.			
A. fistulosum (Var.)	278	1.0	5.75	Welsh Onion	2087	2.3	8.70	Nebuka	4208	17.05	23.89
Welsh Onion	227	2.3	8.70	Nebuka	3194	4.0	11.51	Hishiko	8601	18.55	24.89
Hishiko	216	2.5	9.07	Hardy Hishiko	1850	7.0	15.37				
Hardy Hishiko	272	4.8	12.67	Hishiko	750	7.1	15.49				
				Allium cepa x *fistulosum*				*Allium cepa* x *fistulosum*			
				Beltsville Bunching	1444	39.7	39.05	Beltsville Bunching	2641	44.36	41.60
Allium cepa L.				*Allium cepa* L.							
Autumn Spice	303	13.0	21.15	R. Wethersfield	260	10.3	18.72	R. Wethersfield	4753	44.67	41.92
P.I. 175036	117	17.7	24.89	White Portugal	1967	58.8	50.09	Autumn Spice	5773	46.67	43.06
171475	118	22.9	28.58	Autumn Spice	2838	60.9	51.28	White Portugal	3251	55.15	47.99
164807	140	23.4	28.92	Early Yellow Globe	2189	69.4	56.41	Early Yellow Globe	2600	63.21	53.01
174015	128	24.5	29.69	(Check)				(Check)			
Early Yellow Globe (Check)	248	49.13	57.20								
Diff. necessary for significance at 0.05 =			17.98				8.15				9.62

inches, with two rows two and one half inches apart per flat. In the first test there were three flats of each variety; in the three subsequent tests, four. The seedlings were grown at 50°F., were clipped to approximately one inch above ground level after they had passed the "flag" stage, and were transferred to a screened cage nine by nine by six feet when they were about three inches high. The flies were obtained from pupae collected in the fall from the field and large outdoor rearing cages (Perron et al., 1951), the pupae were stored at 36°F. and high humidity and were subsequently placed in an incubator at 80°F. and high humidity for 10 to 12 days to induce fly emergence. During the four tests, 300 to 600 flies were maintained in the cage and fed molasses, yeast, and evaporated milk (Perron *et al.*, 1951). In each test the onions were exposed to oviposition for 17 to 20 days, and dead plants were counted every second day beginning at the fourth or fifth day. The percentage mortality was determined from the total of the plants left and killed.

Results and Conclusions

Field Tests.—In the field tests in 1955, nine varieties had significantly higher resistance to the onion maggot than Early Yellow Globe (Table 1). Of 35 other varieties tested, all of the *A. cepa* group, 22 suffered 31.8 to 51 per cent mortality, in ascending order as follows: Spotlight, P.I. 175569, 171474, 171476, 175571, Autumn Brown, P.I. 173619, 171478, 164970, Brown Beauty, P.I. 171473, 171481, 176400, 171477, Bunching onions, P.I. 168961, Asgrow Y. 41, P.I. 176392, 172704, 168960, 168965, 168962; 13 suffered 52 to 82.8 per cent mortality; P.I. 175573, Senshu-ki, P.I. 164850, Sapporo-ki, Early Yellow Globe (check), P.I. 174201, 168968, 176394, 177244, 168967, Brigham Yellow Globe, P.I. 176391, and 175574.

In the 1956 tests four varieties of *Allium fistulosum* (L.) (Table I) were significantly more resistant than the varieties of *Allium cepa* x *fistulosum* Beltsville Bunching or of *Allium cepa* (L.) except Red Wethersfield.

In the 1957 tests of the varieties less susceptible than Early Yellow Globe (Table I), Welsh Onion and Hardy Hishiko were discarded due to their close phenotypical resemblance to the varieties Nebuka and Hishiko. Otherwise, the

TABLE II

Results of four greenhouse tests of seven varieties to onion maggot attack, and total number of plants (1956–1957)

Species and variety	Total No. of Plants	End of fourth count		End of seventh count	
		Plant mortality %	Angular transformation	Plant mortality %	Angular transformation
Allium cepa L.					
E.Y. Globe	5669	50.0	45.1	91.2	74.9
Aut. Spice	5386	41.0	39.4	95.3	79.1
R. Wethersfield	4693	44.3	41.9	92.8	75.7
White Portugal	4956	37.6	37.4	88.6	72.1
Allium cepa x *fistulosum*					
B. Bunching	2411	36.7	36.5	85.7	69.3
Allium fistulosum L.					
Hishiko	5129	20.3	25.4	74.4	59.9
Nebuka	5551	14.4	20.4	48.2	43.9
L.S.D. P — 0.05			14.6		12.6

results were identical to those of the 1956 field tests, but Red Wethersfield was found to be definitely susceptible to the onion maggot.

Greenhouse Tests.—The highest resistance in the experiment was obtained with the varieties Hishiko and Nebuka, the latter suffering only 14.4 per cent mortality (Table II). The difference in resistance was more apparent when almost all of Early Yellow Globe were destroyed, Nebuka showed 77.6 per cent mortality (Table II). The difference in resistance were more apparent when the mortality of the check variety was 50 per cent.

Conclusions.—The field and greenhouse tests show that the varieties of *A. fistulosum* were more resistant to the onion maggot than those of *A. cepa*. There is a greater variation in resistance in the field than in the greenhouse. The range of the percentage of plants killed between the most resistant and the most susceptible varieties is much wider in the field than in the greenhouse, probably due to a very restricted choice for the adults to lay their eggs in the greenhouse.

Summary

Field and greenhouse tests of 44 varieties of *Allium* spp. in muck soils showed that Nebuka and Hishiko varieties of *Allium fistulosum* (L.) were significantly more resistant to attack by the onion maggot, *Hylemya antiqua* (Meig.), than the *Allium cepa* x *fistulosum* Beltsville Bunching or the varieties of *Allium cepa* (L.), namely, White Portugal, Autumn Spice, Red Wethersfield, and Early Yellow Globe, the check variety used as the standard of susceptibility in all the tests.

Acknowledgments

The authors acknowledge the assistance of their colleague Mr. M. Hudon in some of the counts made in the greenhouse tests. They are also indebted to Dr. J. L. Auclair, who gave valuable advice on the experimental work and on the preparation of the manuscript.

References

Baker, A. D. and K. E. Stewart. 1928. The onion maggot, *Hylemya antiqua* (Meig.) on the island of Montreal. *20th Ann. Rept. Quebec Soc. Prot. Plants*, 1927-1928, pp. 99-138.

Matthewman, W. G., J. P. Perron, and L. M. Cass. 1953. Varietal responses of seeded onions to the onion maggot. *Canadian Ent.* 85: 153-154.

Perron, J. P., J. Lafrance, and M. Hudon. 1953. Notes on the behaviour of the adult of the onion maggot, *Hylemya antiqua* (Meig.), in captivity. *32nd and 33rd Repts. Quebec Soc. Prot. Plants*, 1950-1951, pp. 144-148.

Sleesman, J. P. 1934. Onion maggot, *Hylemya antiqua* Meig. *In Ohio Agr. Expt. Sta. Bull.* 532 (52nd Ann. Rept.): 41.

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Studies of Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae)

V. *Laricobius erichsonii* Rosen. (Coleoptera: Derodontidae), an Introduced Predator in Eastern Canada[1, 2]

By R. C. CLARK[3] and N. R. BROWN[4]

Introduction

Laricobius erichsonii Rosen. is one of several species that have been introduced into the Atlantic Provinces since 1933 for the biological control of the balsam woolly aphid, *Adelges piceae* (Ratz.). This small beetle occurs commonly on *A. piceae* infestations in Europe where it is one of the more numerous predators of the adelgid (Mesnil, 1950). Franz (1953) described its range in Europe as from the Italian Alps to near southern Denmark and from Normandy almost to the Carpathian Mountains, stating that its distribution is bound to that of the Coniferae on which its prey live. Franz also described the morphology of all stages in detail and discussed the bionomics and ecology in Europe. Prior to these studies the biology of the insect was unknown.[5]

Literature records of *L. erichsonii* in North America have in part been incorrect due to confusion with the native *L. rubidus* Lec. *L. erichsonii* was described by Rosenhauer (1847) from Europe. LeConte (1861) described *L. rubidus* from Washington, D.C. and in more detail in 1866. LeConte and Horn (1883) placed *rubidus* in synonymy with *erichsonii*. Since that time several collections from North America have been mistakenly attributed to *erichsonii*. Leonard (1926) refers to collections from Ithaca and Staten Island, New York. The specimens from the Ithaca collection as well as specimens from Toronto were obtained on loan from the Cornell University collection through the courtesy of Dr. H. Dietrich, Curator of Insects. Mr. W. J. Brown, Insect Systematics and Biological Control Unit, Ottawa, has examined these specimens and determined them as *rubidus*. He stated (personal communication) that this species has also been reported from Michigan, southern Quebec, and New Brunswick. Brown (1944) said that *rubidus* was improperly placed as a synonym of *erichsonii* by LeConte and Horn and differentiated them on characters of the male genitalia, head punctures, colour of thorax and elytra, and distribution. Thus it appears that *erichsonii* was not present in North America prior to liberations in New Brunswick in 1951.

Two other North American species are known, *L. laticollis* Fall (1916) collected from Douglas fir in Washington, and *L. nigrinus* Fender (1945) from Oregon and British Columbia. Information on prey and biology is lacking for all three North American species.

A major effort to introduce *L. erichsonii* on infestations of *A. piceae* in eastern Canada has been made because of its occurrence in large numbers on adelgid infestations in Europe and its apparently near-specific feeding habits. The European workers found that adults were not parasitized and could be collected in large numbers when they emerged from hibernation. It was be-

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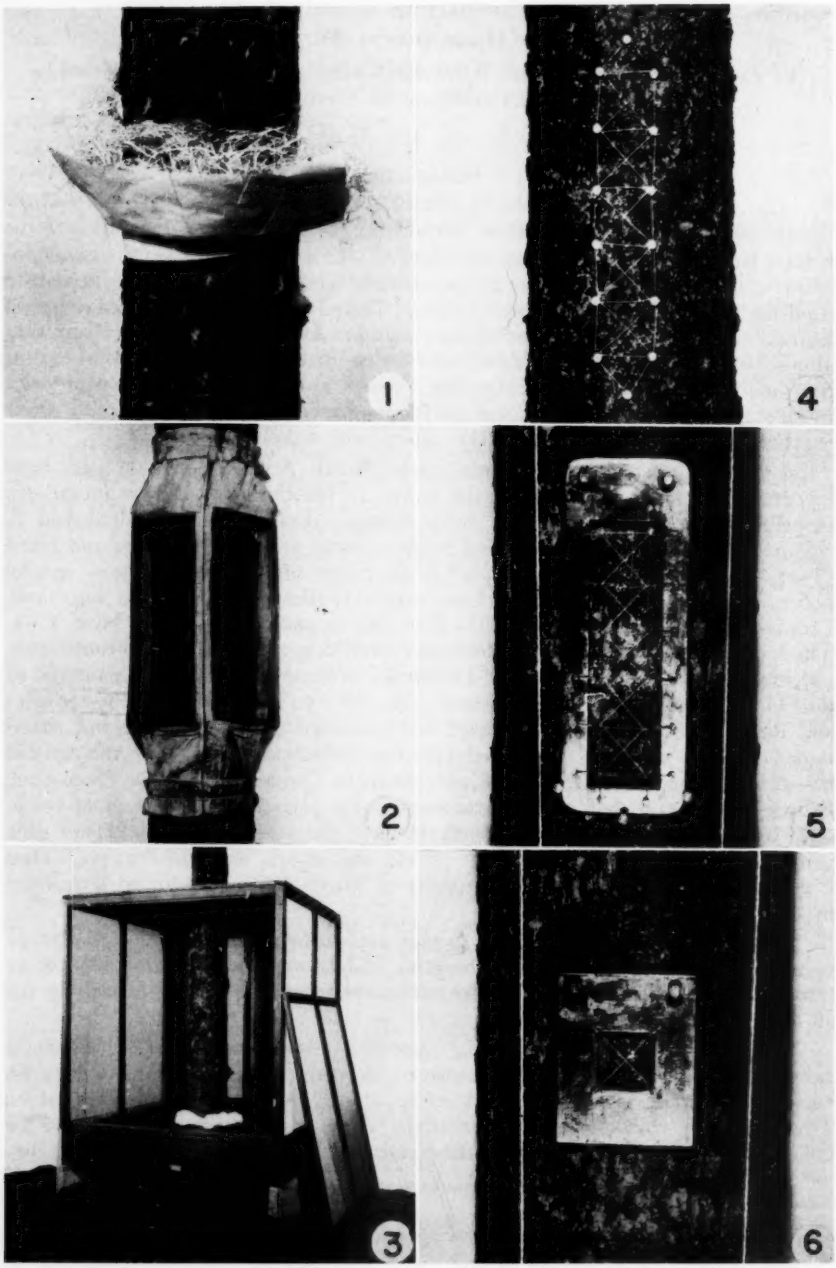
[5]Since writing we have received a copy of the following paper which gives an exhaustive account of work on this insect in Europe.

Franz, J. 1958. Studies on *Laricobius erichsonii* Rosenh. (Coleoptera: Derodontidae), a predator of Chermesids. Entomophaga 3(2): 109-196.



Figs. 1-6. 1. Open release method on paper shelf. 2. Sleeve cage used for controlled releases. 3. Large release cage with removable screens. 4. Map pins used in 1951 to delineate five-square-inch sampling area. 5. Five-square-inch metal grid used for sampling in 1952. 6. One-square-inch metal grid used for sampling 1953-1957.

lieved that the habit of overwintering as an adult in the ground would allow the species to become acclimatized to Canadian conditions without difficulty (Mesnil, 1950).

Liberations

In all cases *L. erichsonii* adults were released in areas of heavy *A. piceae* stem infestations where a plentiful supply of prey was available to facilitate survival. Two methods were used – free release at the bases of infested trees, or release in cages around infested trunks. In the free release method a sheet of paper was tied to the trunk of the infested tree and folded to form a shelf (Fig. 1). The insects were transferred from the shipping tins to the paper shelf. From there they were able to fly or crawl to the infested bark. A sleeve-type cage constructed of close-mesh wire or plastic screen with factory cotton ends and closed with a long zipper (Fig. 2) was used on some occasions to confine the insects temporarily on the trunk in an attempt to ensure mating before the adults dispersed. A few adults were confined in large cubicle cages (Fig. 3) where studies on devlopment, seasonal history, and predator-prey interactions were carried out. In all cases the insects, which were shipped in iced containers, were kept for a short period at room temperature prior to release.

In 1951 and 1952 *L. erichsonii* was released only in the vicinity of Fredericton, N.B. in stands at least 3/4 mile apart. This was to facilitate the study of local spread immediately following release, and was also a precaution against losing the insects from unexpected causes such as fire or cutting. Beginning in 1953 releases were made at other places in the Atlantic Provinces. In New

TABLE I
L. erichsonii Liberations in the Atlantic Provinces, 1951–1955

Locality	No. released	Year
New Brunswick		
Area 2, U.N.B. Forest, Fredericton	489	1951
Area 3, U.N.B. Forest, Fredericton	699	1951
Area 4, U.N.B. Forest, Fredericton	937	1951
Area 6, U.N.B. Forest, Fredericton	836	1951
Area 7, U.N.B. Forest, Fredericton	50	1951
Area 8, U.N.B. Forest, Fredericton	1885	1952
Area 9, Hanwell Rd., Fredericton	4135	1953
Area 10, O'dell Forest, Fredericton	4023	1953
Area 11, Fredericton	964	1953
Scotch Ridge, Charlotte Co.	231	1954
Oak Bay, Charlotte Co.	3567	1954
Salisbury, Westmorland Co.	2081	1954
Rexton, Kent Co.	2131	1954
Tabusintac, Northumberland Co.	595	1954
Nova Scotia		
Earltown, Colchester Co.	112	1954
Harrison Sett., Cumberland Co.	870	1955
Newfoundland		
Robinson's Sta.	843	1952
Flat Bay Brook	2502	1954
Nardinis	1278	1955
Pulpwood Siding	892	1955
Little Barachois Bk.	1399	1955
St. George's	250	1955
Jeffreys	1485	1955
Corner Brook, 45 ml. W.	120	1955

Brunswick all such liberations were made at least 50 air miles from Fredericton as an aid in studying long-distance spread. Table I lists all releases and their location is shown on the accompanying maps (Figs. 7, 8, and 9).

In 1955 two releases were made in the U.S.A. — 489 at Searsburg, Vermont, and 494 at Woodstock, New Hampshire.

Establishment and Spread

Surveys were made in each release area every year since liberation to determine whether or not the species had become established and, if so, to determine the extent of spread and area of distribution. The surveys were carried out at one or both of two periods in the life cycle: oviposition period in the spring or peak occurrence of larvae later in the season. The latter time is better because of the greater number of individuals present. There is also

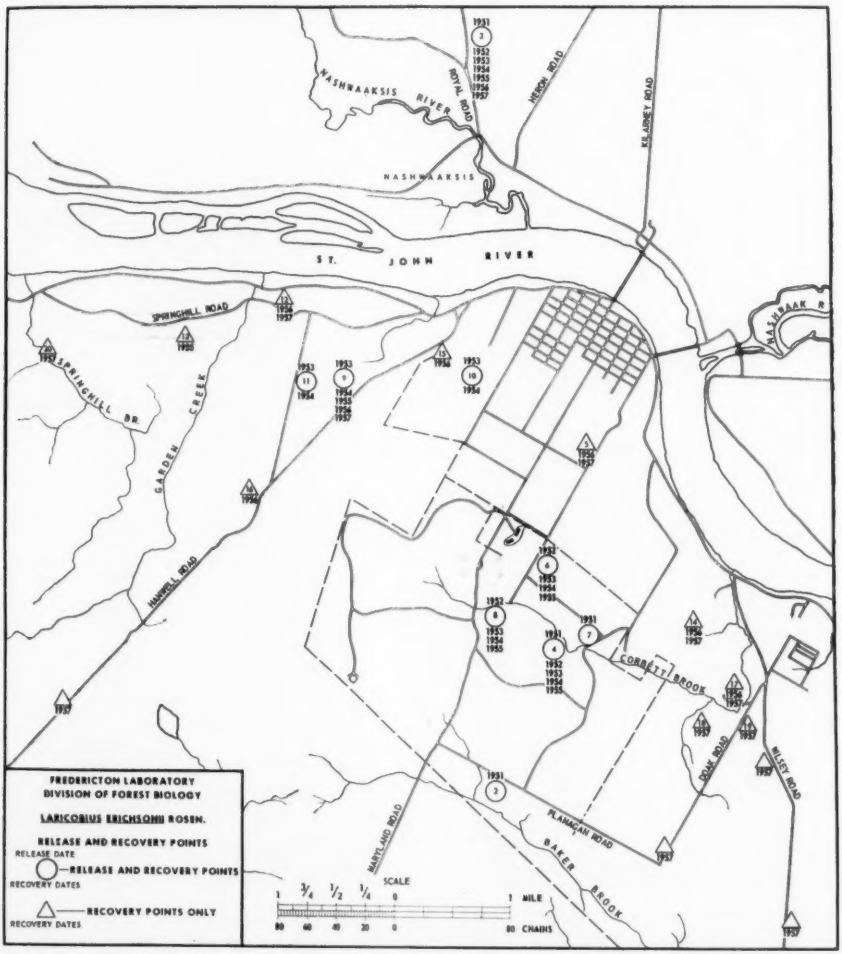


Fig. 7. *L. erichsonii* liberation and recovery points in the vicinity of Fredericton.

a period following pupation during late summer when newly-emerged adults may be found but they are not encountered in as large numbers at this time as during the oviposition period in the spring.

In making the surveys, observations were made on all degrees of prey infestation, by examining trees in all directions from the liberation points. Normally, only the basal 6 feet of the trunk were examined, from five to ten minutes being spent per tree, depending on infestation intensity.

Between 1951 and 1954 *L. erichsonii* adults were released at nine areas in the vicinity of Fredericton. At two of these points the releases were apparently unsuccessful as the species was not found in subsequent seasons. In the other areas recoveries were made in the years following release to a maximum of six years in one area. The relative abundance of larvae and adults has varied from area to area and from year to year depending largely on the prevalence of adelgid-infested trees. In two of the areas lumbering operations from three to four years after the insects were liberated removed all infested trees. The insects had, however, spread from these areas prior to cutting. In uncut areas, where the number of infested trees and the adelgid population on infested trees change from year to year, *L. erichsonii* has been recovered almost every season since release. Establishment has occurred on trees with prey population as low as two per square inch but it is unusual to find larvae on trees with less than ten developing *A. piceae* per square inch.

This beetle spreads from release points very slowly. During the year of release the maximum spread observed was 75 yards. In the year following release, maximum observed spread in different areas varied from none to 485 yards. Slow additional spread has been recorded in most areas each year since

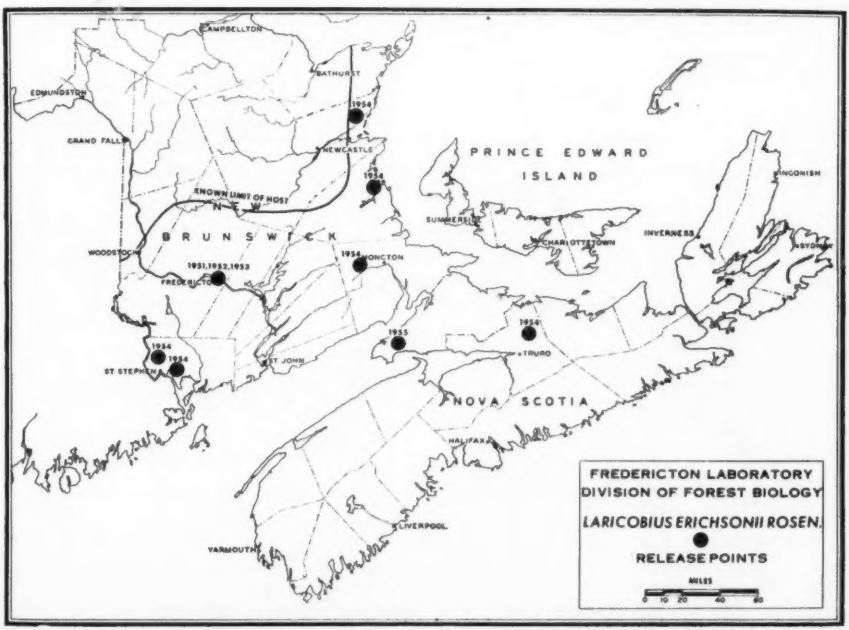


Fig. 8. *L. erichsonii* liberation points in New Brunswick and Nova Scotia.

release. By 1957 maximum observed spread was 4 miles in a westerly direction from Area 9, where a northwest spread of 1 1/2 miles was recorded in 1956, and 3 3/4 miles in a southeasterly direction from Area 4 (Fig. 7). Additional spread recorded in 1957 was much greater than that recorded in any other season since release of the species.

It is probable that spread has occurred to greater distances than have been recorded. Small numbers of a species of such small size scattered over an increasingly large area are extremely difficult to observe and, as the area of distribution has become larger, it has not been possible to examine as large a percentage of trees as could be done in the immediate vicinity of release in the year or two following liberation. In 1957 it was found that at points of maximum spread more individuals were recovered from infested trees than in previous years. This could occur because of natural increase of the predator, or fewer infested trees following severe winter mortality of the host resulting in a concentration of the predators on these trees. The fact that *L. erichsonii* can be found in almost all infested stands between release points and the points of maximum recorded spread is proof of the successful establishment and increasing population near Fredericton.

It has been impossible to keep as close check on the establishment and spread of *L. erichsonii* from the other liberation points in New Brunswick. Most of them have been visited once each year since release. At Scotch Ridge a spread of 400 yards was recorded in the year following release. In 1956 and 1957 the infestation had died out and the predator was not recorded. At Oak Bay a spread of 1000 yards was recorded in the year following release. No additional spread was noted in 1956 but the predator was more numerous than in

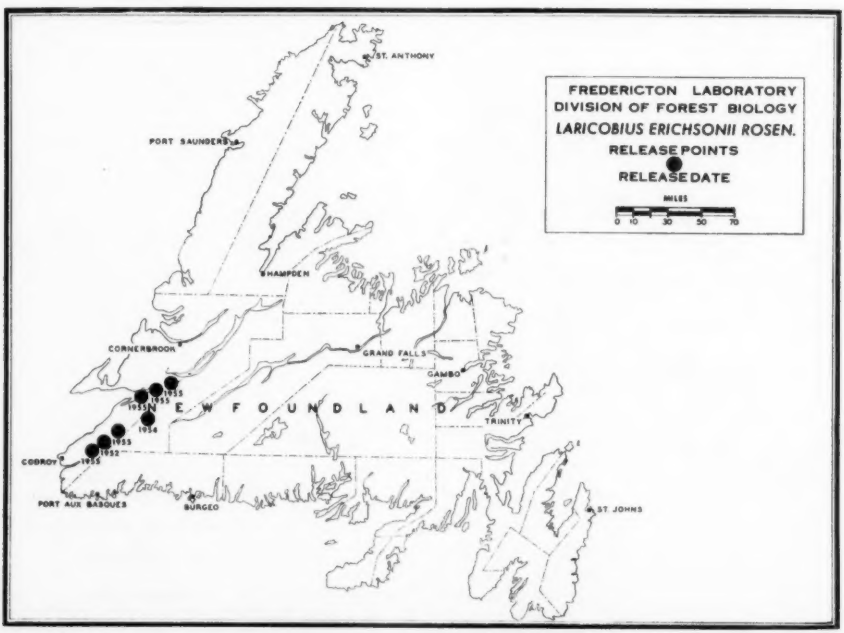


Fig. 9. *L. erichsonii* liberation points in Newfoundland.

the previous year. Infested trees were scarce in this area in 1957 and the predator was not found. At Salisbury and Rexton *L. erichsonii* was found only in the immediate vicinity of the release area in the year following release. In 1956 and 1957 it was not found in these areas and infested trees were extremely few in number. It is too early to say whether these liberations were successful.

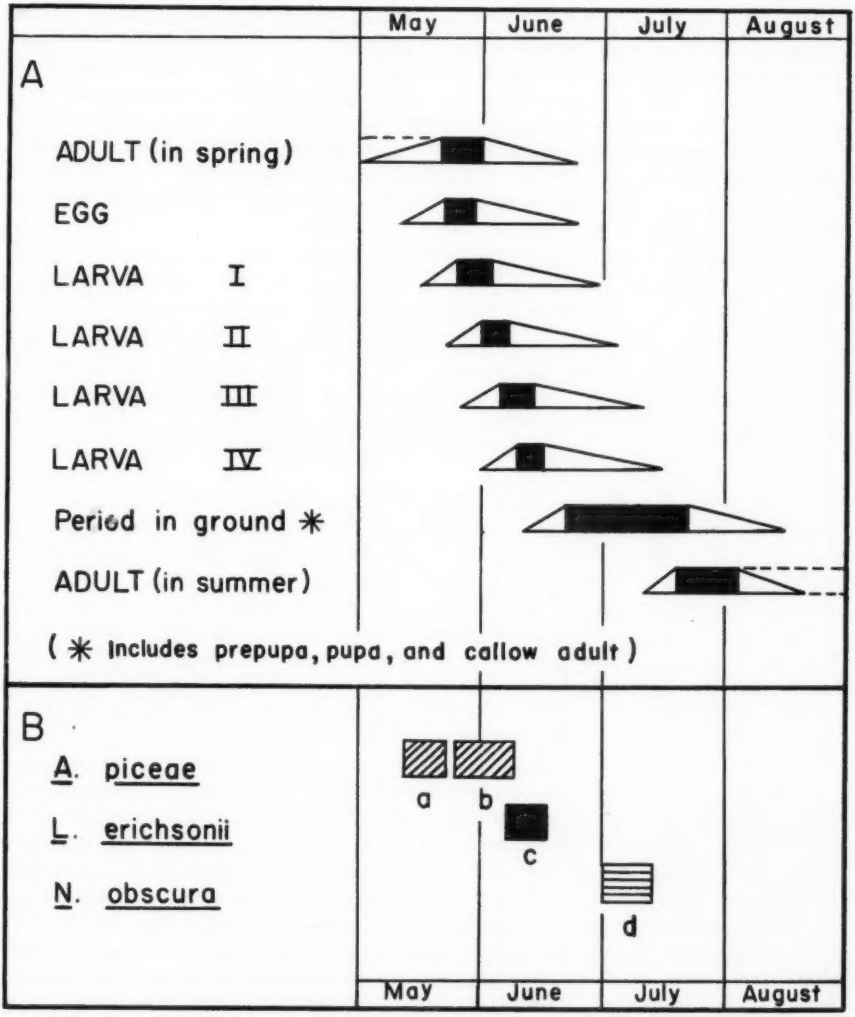


Fig. 10. A. Life cycle of *Laricobius erichsonni* Rosen. based on data from 1951 to 1957. Solid areas represent normal periods of occurrence; clear areas indicate extreme ranges. B. Development of some stages of *A. piceae*, *L. erichsonii* and *N. obscura* based on data from 1951 to 1957. (a) May 11-22. First *A. piceae* eggs laid by hiemosistentes. (b) May 24 - June 8. Maximum *A. piceae* intermediate stages and adults, hiemosistentes. (c) June 6-16. Maximum *L. erichsonii* larvae. (d) June 30-July 12. Maximum *N. obscura* larvae, summer generation.

No information is available on the establishment or spread of this insect from the release points in Nova Scotia and Newfoundland.

Life History and Habits

Seasonal development, based on records for seven seasons (1951 to 1957), is shown graphically in Figure 10.

Adult beetles that have overwintered in the ground were first observed on the trees from May 1 to May 14, depending on seasonal conditions, and have been found as late as June 23. The date of peak adult population in the 7-year period has varied from May 20 to June 8. Observations of adults on single sample trees have extended over periods of up to 37 days. During at least the first half of this period the adults are engaged in mating and oviposition. The majority of eggs are laid by the end of May. The unusual method of copulation, described in Europe by Franz (1953) in which the male mounts the female on the side, sometimes with a second male attached to the opposite side, has been observed on numerous occasions. Mating has been recorded from May 14 to June 19.

Food of the adult beetles during this period consists mostly of *A. piceae* eggs, although some intermediate stages and adults are also consumed. Beetles have not been observed feeding on any prey other than *A. piceae*.

Franz (1953) described the small greenish-yellow eggs, which are laid singly in or between the adelgid egg masses. We have observed them in the laboratory but not in the field. From observations on adults and larvae, the normal period of occurrence of eggs should be from May 10 to June 25 with maximum abundance from May 20 to May 30. Franz estimated that about 50 eggs are produced per female.

First-instar larvae have been observed in the field as early as May 30. As newly-hatched larvae are very difficult to see in the masses of adelgid eggs and "wool", this stage probably occurs in the field earlier than this, possibly as early as May 15. Last-instar larvae have been seen as late as June 30 and a few may be present up to the middle of July. Observations of larvae on single sample trees have ranged up to 40 days but they are usually seen on single trees for approximately three weeks. The date of peak larval population in the 7-year period has varied from June 6 to June 16. Smith (Brown, Clark, and Smith, 1952), from laboratory observations, has estimated the length of larval life as approximately 17 days and this checks with field observations as shown in Figure 10.

A. piceae eggs form the preferred food of all larval instars although later instars also consume some intermediate stages and adults. The method of feeding, whereby the prey is punctured and the fluid contents of the eggs or other stages are pumped in and out several times before final ingestion has been described by Franz (1953). Larvae have been found feeding only on *A. piceae*.

First- and second-instar larvae feed in the masses of *Adelges* eggs and "wool" and move about very little. Later instars search out additional food, moving slowly over the trunk of the tree. Searching appears to be at random; the larvae have often been observed to pass very close to large egg masses, apparently unaware of the presence of this food material. These observations suggest that senses for locating prey are poorly developed in the larva. It has, however, been observed on many trees that areas supporting numerous prey which have been by-passed by the predator larvae are eventually cleaned up before the feeding period is completed. These areas have in some cases been almost completely surrounded by lines of pitch flowing from wounds or

abrasions in the bark, leaving only a small entrance of dry bark to them. This entrance has eventually been discovered by the predators when food on the remainder of the trunk has been consumed.

Larvae in all instars are covered with small bits of *Adelges* "wool" which adhere to a sticky substance secreted by the larval epidermis. The presence of this white covering makes detection very difficult in the early instars when the larvae are feeding within the egg mass. In later instars this covering still provides excellent camouflage, and the larvae, even on relatively clear areas of the trunk, are difficult to observe unless in motion. Last-instar larvae are often seen without this white covering, particularly on areas of the trunk where the prey is present in small numbers.

At the peak of the larval feeding period, counts of last-stage larvae declined rapidly in the course of one or two days. Since the time appeared to be too short for them to crawl to the ground, an experiment was set up to determine whether they dropped to the ground on completion of feeding. A 3 by 3 feet cloth cut to fit around the stem and marked off into 2-inch squares was placed flat on the top of a 12-foot high platform which had previously been erected for population studies. On June 21, 1955, observations were made at 15-minute intervals from 9:30 a.m. to 4:15 p.m. and the position and movement of any larvae noted. In addition, four cotton sheets 18 by 36 inches were staked out on the ground from 8 to 10 feet from the trunk at the cardinal points to determine whether larvae drop to the ground at this distance from the trunk. These were also examined at 15-minute intervals. During the period the weather was calm and sunny and the temperature ranged from 70 to 75°F.

Fourth-instar larvae dropped to the cloth on the 12-foot platform on completion of feeding. At least 33 dropped between 9:30 a.m. and 4:15 p.m. After landing on the cloth they crawled towards the edge and dropped again from the platform to the ground. The drop is apparently intentional since the larvae curled up before dropping from the edge of the cloth. No constant direction of movement on the cloth was noted. Although the majority moved towards the trunk, some wandered about apparently aimlessly and others crawled towards the outer edge. The rate of movement ranged from 0.5 inches to 6.0 inches per 15-minute interval and averaged 0.25 inches per minute (24 observations). More rapid locomotion has been observed on the tree trunks. Distances travelled by individual larvae ranged from 6.0 inches in 15 minutes (0.4 inches per minute average) to 37.5 inches in 2¼ hours (0.19 inches per minute average). No larvae dropped on the four sheets on the ground.

When the fully-fed larvae reach the forest floor, by crawling down the trunk or dropping, they burrow through the litter and duff into the mineral soil. Smith (Brown, Clark, and Smith, 1953) examined the soil at the base of ten trees to determine the distribution of larvae and pupae in the soil. Eighty-one per cent of the larvae found in the ground were in the first 2 inches of mineral soil although a few penetrated as deep as 6 inches. Sixty-six per cent of the pupae were found in the first 2 inches of mineral soil, 25 per cent in the third and fourth inches, and the remainder in the litter and in the fifth and sixth inches of mineral soil. Maximum abundance of larvae and pupae found during these observations was one per 16 cubic inches of soil, or one per 0.1 square feet of surface. Neither larvae nor pupae were found in dry soil.

After the larvae enter the soil they form a "cocoon" by compacting the soil particles around them, probably with the aid of a secretory material. These "cocoons" look like small oval pieces of soil about ¼ inch in length. Pupation occurs from three to five days after the larvae enter the soil. The

pupal stage lasts approximately two weeks and the callow adults do not issue from the "cocoons" for a few days after they emerge. The usual period spent in the ground at this time is from about June 20 to July 20.

In the 7-year period newly-emerged adults have been seen on the trees at dates ranging from July 11 to August 22 and over a maximum period of 35 days in any one year. Probably individual adults are active for about one month at this time. Following this period the adults once again enter the soil and remain there until the following spring. From observations made in 1951 and 1952 and reports by Mesnil (1950) from Europe, the adults overwinter in the mineral soil at a depth of from 1 to 4 inches.

A comparison of this seasonal history with that shown diagrammatically by Franz (1953) for Germany shows a constant difference. The dates given by Franz for the beginning of each developmental stage are approximately two weeks earlier than for central New Brunswick (Fig. 10). Last dates of occurrence for the various stages in Germany are from three to 15 days later than in New Brunswick, except for the active period of new adults, which extends to the end of September in Germany.

Natural Control

Mesnil (1950) records that *L. erichsonii* larvae are parasitized by *Plectiscus* sp. in Europe. Franz (1953) records the presence of an ichneumonid larval parasite, *Echthrolaricobius paradoxus* Perkins. Parasitism has not been found in Canada, but very few field-collected larvae have been reared. It is possible that one or more of our native parasite species may be able to use this introduced insect as a host, particularly since the nearctic species *L. rubidus* has been recorded in New Brunswick.

Franz (1953) described a disease which was responsible for considerable larval mortality in Europe. To date we have found no evidence of disease in Canada.

Franz states that several species of coccinellids, syrphids and chrysopids that are normally predacious on adelgids in Europe are known to attack larvae of *L. erichsonii*. The only predation we have observed in Canada is that of an ant, *Myrmica lobicornis fracticornis* Emery, feeding on a larva.

Winter soil conditions in areas where *L. erichsonii* was present were determined during February or March of each year, 1953 to 1955 inclusive, by digging soil pits to a depth below frost. The condition of the litter, humus and mineral soil layers was described.

Conditions ranged from a deep snow cover over unfrozen humus and mineral soil in February 1955, to one foot of snow over six inches of ice, a completely frozen humus layer and up to 11 inches of frozen mineral soil in March 1953. As adults overwinter in the top layers of the mineral soil, it might be expected that the winter conditions in the soil would affect survival and emergence the following spring. Although no figures on actual survival are available, observations each spring in infested stands indicate that the adults emerged in numbers greater than were present in the same areas during the emergence period of the previous summer. These observations, combined with the fact of establishment in most liberation areas and continuing spread of the species over a 6-year period, are evidence that overwintering mortality is not a serious limiting factor.

Population Studies

Methods of Sampling

The purpose of population sampling in the study of the introduced and native predators is to accumulate sufficient data for both prey and predator

so that an assessment may be made of the relative value of the predators both singly and in combination. Sampling also provides a means of determining the level of prey population at which the predators become established. Frequent sampling is necessary without disturbing either the prey or the predators.

Since 1951 three slightly different methods have been used in the development of a satisfactory sampling technique. Early in 1951 preparations were made for sampling by marking out sample units on suitable trees in several of the general liberation areas on or near the University Forest at Fredericton. In each, trees with moderate to heavy *A. piceae* infestations were selected. On each tree four areas of five square inches each were delineated, one at each cardinal direction (N, E, S, W). These areas were between 3 and 5 feet from ground level and were selected to represent the average infestation condition for the side of the tree concerned.

Map pins with coloured heads were driven through the bark into the wood so that an area 1 by 5 inches extending vertically up the trunk was outlined. Additional pins were then used to mark the corners of 1-square-inch sub-areas and these were outlined with thread (Fig. 4). Later in the same season it was found that the presence of the pins resulted in a heavy pitch flow which often interfered with sampling. To overcome this, a specially constructed metal grid outlining an area of 1 by 5 inches was used (Fig. 5). This was hung on two nails and could be removed and subsequently replaced in the same position. One of these 5-square-inch samples was studied on each of the four cardinal sectors of the lower 5-foot trunk section of each sample tree.

In addition to counting both prey and predators on the four 5-square-inch areas, the predator stages were also counted on a 5-foot section of the sample trees which was marked off with horizontal strings at approximately the 1- and 6-foot trunk levels.

In 1953 after careful examination of the 1951 and 1952 results, it was considered necessary to obtain a more representative prey population sample from the 5-foot trunk section. As a refinement of the four 5-square-inch counting areas, twenty 1-square-inch sample areas were used. These were distributed over the 5-foot trunk section using five per cardinal sector, 12 inches apart vertically. This gave a more representative sample of prey populations and made comparison with predator counts more significant.

A metal counting grid with a 1-square-inch opening divided diagonally by heavy thread was used (Fig. 6). This was hung from two aluminum nails placed far enough apart to prevent resin affecting the sample area.

On each area weekly or twice-weekly counts of the number of *A. piceae* intermediate stages (instars II and III) and adults were made with the aid of a hand lens. The general abundance of crawlers and dormant neosistentes as well as the number of the various stages of predators of all species observed was recorded. In addition to the above counts, a careful count of all predator stages found on the 5-foot trunk section was made at each examination. These latter counts were made with the naked eye, using a hand lens only when necessary for positive identification.

During the year of liberation in each area, the trees sampled were those on which liberations were made. In some cases these same trees were studied in subsequent years, as well as trees to which the predator had spread since liberation. In most instances the trees sampled were moderately to heavily infested and had just recently reached these infestation intensities.

Population studies of this predator under laboratory and field-cage conditions were carried out by B. C. Smith (Brown and Smith, 1951; Brown,

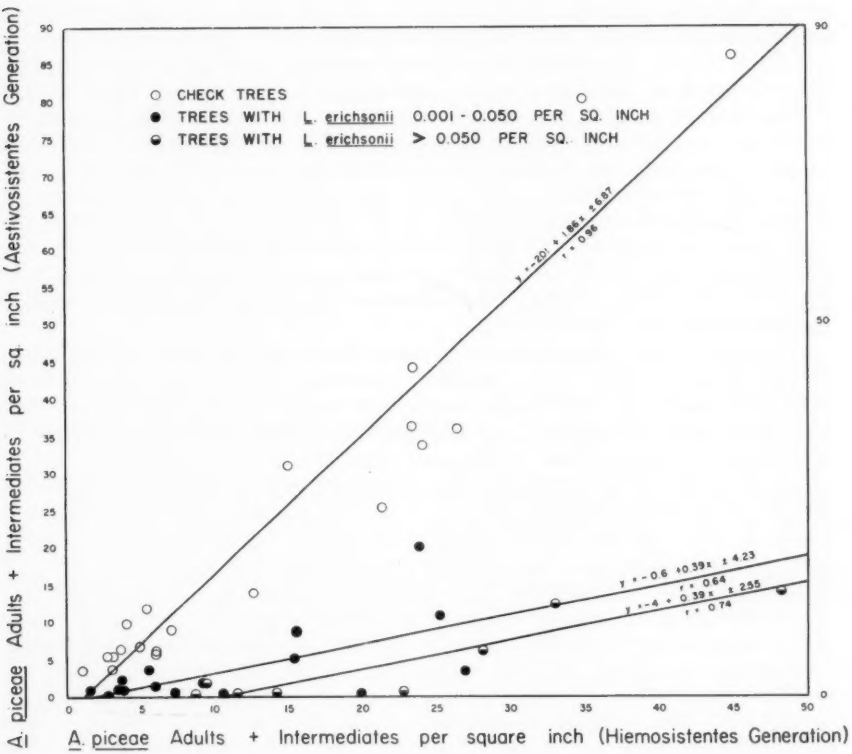

CHECK TREES
TREES WITH L. erichsonii 0.001 - 0.050 PER SQ. INCH
TREES WITH L. erichsonii > 0.050 PER SQ. INCH
A. piceae Adults + Intermediates per sq. inch (Aestivosistentes Generation)
A. piceae Adults + Intermediates per square inch (Hiemosistentes Generation)

Fig. 11. Scatter diagrams for the regression analyses of *A. piceae* populations aestivosistentes generation on hiemosistentes generation) for three groups of sample trees with different levels of *L. erichsonii* populations.

Clark, and Smith, 1952). These studies will be dealt with in detail in a forthcoming paper by Smith.

Analysis

To understand fully the relationship between prey and predators, complete life tables are necessary. Insufficient data are available at present for the compilation of life tables but the data at hand seem to provide evidence regarding the control exerted by *L. erichsonii*. They have been analysed to determine whether there is any consistent relationship between the presence of the predator and the population trend of the prey from the hiemosistentes to the aestivosistentes generation. The figures used in the analysis were obtained from the regular sampling of trees which were apparently similar in growth habits and prey infestation intensities, and on which the prey population did not appear to be affected by other variables such as the formation of secondary periderm. For the prey, the average of the three highest counts for each generation (total of adults and intermediate stages) was used. For *L. erichsonii* the maximum larval count was used.

The trees used in the analysis were grouped according to the absence or presence of the predator and the latter group was subdivided into two groups

TABLE II

Significance Tests to Show Difference in Slope and Position of Regression Lines in Fig. 11

Test	Regression lines	t	n	P
Difference in slope	Check vs. *L. erichsonii* low	8.3	32	<0.001
	Check vs. *L. erichsonii* high	10.35	26	<0.001
	L. erichsonii low vs. *L. erichsonii* high	0	22	
Difference in position	Check vs. *L. erichsonii* low	28.6	32	<0.001
	Check vs. *L. erichsonii* high	28.4	26	<0.001
	L. erichsonii low vs. *L. erichsonii* high	14.0	22	<0.001

based on predator density, as follows: (1) 20 "check trees", on which the predator complex as it existed prior to the introduction of *L. erichsonii* was present; (2) 16 trees on which *L. erichsonii* larvae numbered from 0.001 to 0.050 per square inch; (3) 8 trees on which *L. erichsonii* larvae numbered over 0.050 per square inch. The predator complex as in (1) was also present in the latter two groups.

Regression analyses were carried out and scatter diagrams drawn (Fig. 11). In the diagrams Y = *A. piceae* population in the aestivosistens generation and X = *A. piceae* population in the hiemosistens generation. The significance tests of the relationship between the regression lines are shown in TableII.

Fig. 11 shows that on all the "check trees" there was an increase from the hiemosistens to the aestivosistens generation averaging 186 per cent. On all the trees with *L. erichsonii* there was a decrease, averaging 61 per cent. The differences between the regression lines of these two main groups are significant and appear to be due solely to the presence or absence of this predator. The data support our observations that the normal increase from the hiemosistens to the aestivosistens generation is reversed by *L. erichsonii* shortly after it becomes established on a tree. The data, however, are insufficient to indicate any clear relationship between the amount of decrease and the numbers of the predator.

Control Value

In a previous paper (Brown and Clark, 1957) it was shown that the introduced chamaemyiid predator *Neoleucopis obscura* (Hal.) did not give effective control of prey populations for two reasons. The larvae feed too late in the developmental period of both generations of the prey to prevent the laying of large numbers of eggs, a stage which is very seldom eaten (Fig. 10B-a, b, d). Also, this predator increases at a slower rate than *A. piceae.*

The time of occurrence of maximum numbers of *L. erichsonii* larvae (Fig. 10B-c) is approximately three weeks earlier than that for *N. obscura* and is only a few days later than that for intermediate stages and adults of *A. piceae.* Thus maximum predation occurs when the prey is most numerous. This, combined with the feeding habits of the larvae, which prefer eggs but also consume intermediate stages and adults, results in a very rapid decrease in prey numbers. This decrease produces a downward trend of population in the aestivosistentes generation since very few eggs have hatched by this time. At present *L. erichsonii* is the only species in the predator complex at Fredericton which is

present in large numbers at a time earlier than maximum *N. obscura* larval occurrence. Larvae of another recently introduced species, *Pullus impexus* (Muls.) (Coleoptera: Coccinellidae) feed still earlier but this species has so far not shown an ability to increase to large numbers, despite its continued presence since it was introduced in 1951. A few species of native syrphids also feed earlier than *L. erichsonii* but are usually not numerous and have never been observed to exert effective control of the prey.

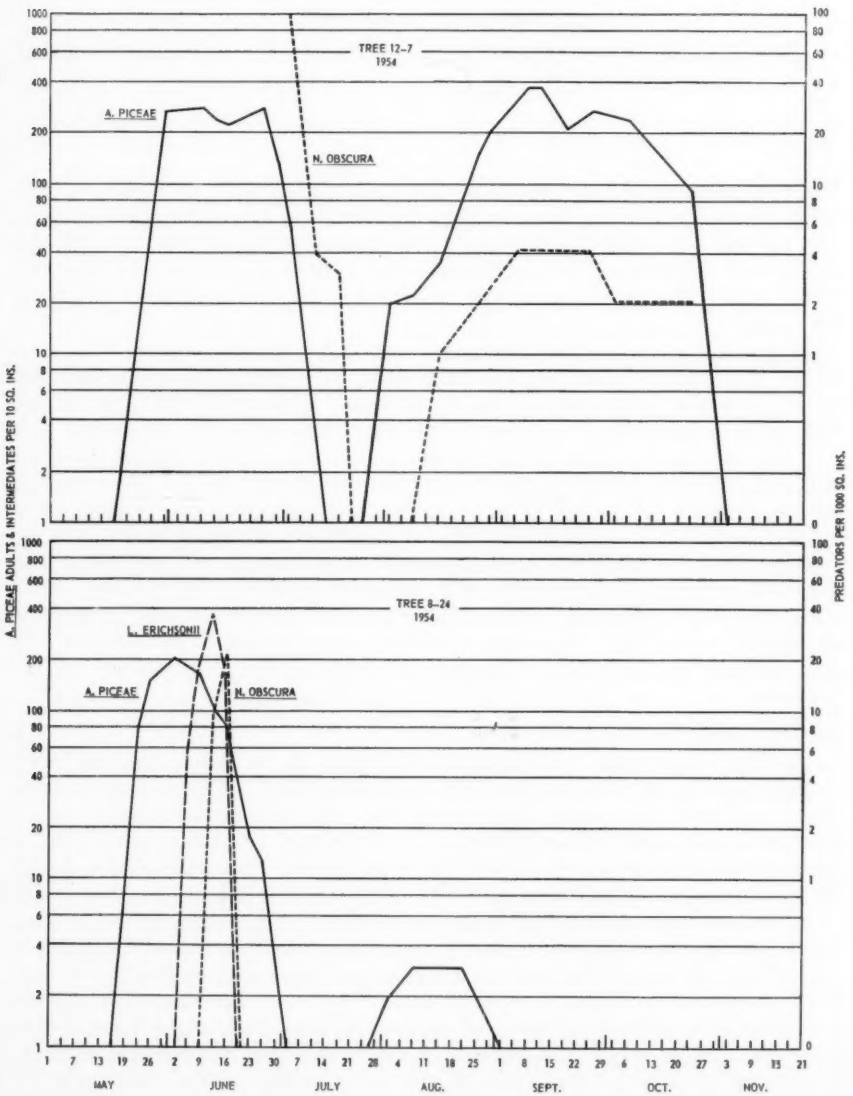


Fig. 12. Graph showing *A piceae* seasonal development on trees with and without *L. erichsonii*. Tree 12-7 — without *L. erichsonii*. Tree 8-24 — with *L. erichsonii*.

Sampling on some trees has shown the potential ability of *L. erichsonii* to control *A. piceae*. Prior to the introduction of *L. erichsonii* it was found that, in the presence of native predators and the introduced *N. obscura*, the prey population increased approximately 186 per cent from the hiemosistentes to the aestivosistentes generation (e.g. Tree 12-7 in Fig. 12). On trees on which *L. erichsonii* was present in numbers over 0.001 per square inch the aestivosistentes generation was reduced to an average of 39 per cent of the hiemosistentes generation (e.g. Tree 8-24 in Fig. 12).

Summary

1. The literature on the genus *Laricobius* in North America is reviewed.
2. *A. piceae* is the chief prey of *L. erichsonii* in Europe and is the only species on which it has been recorded feeding in Canada.
3. *L. erichsonii* has been liberated in New Brunswick (1951-54), Nova Scotia (1954-55), and Newfoundland (1952-55).
4. Establishment has occurred at most release points. The predator apparently spreads slowly, a maximum of 4 miles having been recorded after five years at Fredericton.
5. The life cycle in Canada and notes on the biology of *L. erichsonii* are given. It is a univoltine species, overwintering as an adult in the ground. The larvae feed on the developing stages and adult of the hiemosistentes prey generation, but prefer the eggs of the aestivosistentes generation.
6. No parasites, predators or disease of *L. erichsonii* have been observed and the climatic conditions of the years 1951-1957 have permitted the predator to become established and spread.
7. Population sampling methods for prey and predators are described.
8. Prey population trends in the absence and presence of *L. erichsonii* are compared and an analysis of the predation by *L. erichsonii* is made. This shows that when the predator is present the normal upward trend from hiemosistentes to aestivosistentes generation was reversed.
9. *L. erichsonii* is more effective than *Neoleucopis obscura* because the peak larval feeding period occurs at an earlier date and because the larvae destroy prey eggs. This has resulted in an almost complete loss of the aestivosistentes prey generation.

Acknowledgments

The writers wish to express appreciation to Mr. W. J. Brown of the Insect Systematics and Biological Control Unit, Ottawa, for identification of species involved in this paper and to Mr. E. B. Bates of the Forest Biology Laboratory, Fredericton, for many of the photographs. Thanks are also extended to Dr. R. E. Balch, Dr. R. F. Morris and Mr. C. A. Miller of the Forest Biology Laboratory, Fredericton, for critical review of the manuscript.

Literature Cited

Brown, N. R., and B. C. Smith. 1951. Studies on *Adelges piceae* (Ratz.) and its predators. *In* Annual Reports of Forest Biology Laboratory, Fredericton, N.B., and Entomology Laboratory, Belleville, Ontario. (Joint report, unpublished.)

Brown, N. R., and R. C. Clark. 1957. Studies of predators of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae). IV. *Neoleucopis obscura* (Hal.) (Diptera: Chamaemyiidae), an introduced predator in eastern Canada. Canadian Ent. 89(12): 533-546.

Brown, N. R., R. C. Clark, and B. C. Smith. 1952. Studies on *Adelges piceae* (Ratz.) and its predators. *In* Annual Reports of Forest Biology Laboratory, Fredericton, N.B., and Entomology Laboratory, Belleville, Ontario. (Joint report, unpublished.)

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Brown, N. R., R. C. Clark, and B. C. Smith. 1953. Studies on *Adelges piceae* (Ratz.) and its predators. *In* Annual Reports of Forest Biology Laboratory, Fredericton, N.B., and Entomology Laboratory, Belleville, Ontario. (Joint report, unpublished.)
Brown, W. J. 1944. Some new and poorly known species of Coleoptera, II. Canadian Ent. 76(1): 4-10.
Fall, H. C. 1916. Three new Coleoptera from Washington State. Bull. Brooklyn Ent. Soc. XI: 13-14.
Fender, K. M. 1945. A new *Laricobius* from Oregon (Coleoptera, Derondontidae). Pan-Pacific Ent. 21(4): 152.
Franz, J. 1953. *Laricobius erichsonii* Rosenhauer (Col., Derodontidae), ein Raüber an Chermesiden. Zeitschr. f. Pflkrankh. und Pflsch. 60(1): 2-14. (With summary in English.)
Leonard, M. D. (ed.) 1926. A list of the insects of New York. Cornell. Univ., Agric. Exp. Sta., Ithaca, Mem. 101.
LeConte, J. L. 1861. Classification of the Coleoptera. Smithsonian Misc. Coll. Part I.
LeConte, J. L. 1866. New species of North American Coleoptera, part 1, 2nd ed. Smithsonian Misc. Coll. VI, no. 167: 1-177. (p. 69.)
LeConte, J. L. and G. H. Horn. 1883. Classification of the Coleoptera of North America. Smithsonian Misc. Coll. 507. (p. 220.)
Mesnil, L. P. 1950. Première étude sur *Adelges piceae* Ratz. [Report on the investigations of *Adelges piceae* Ratz. and its natural enemies in Europe during the year 1950.] (Unpublished manuscript.)
Rosenhauer, W. D. 1847. Beitrage zur Insecten-Fauna Europas. Bd. 1. Erlangen.

(Received Sept. 2, 1958)

A New Species of Aphid From *Rubus parviflorus* Nutt.

By Alex R. Hill
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Scotland

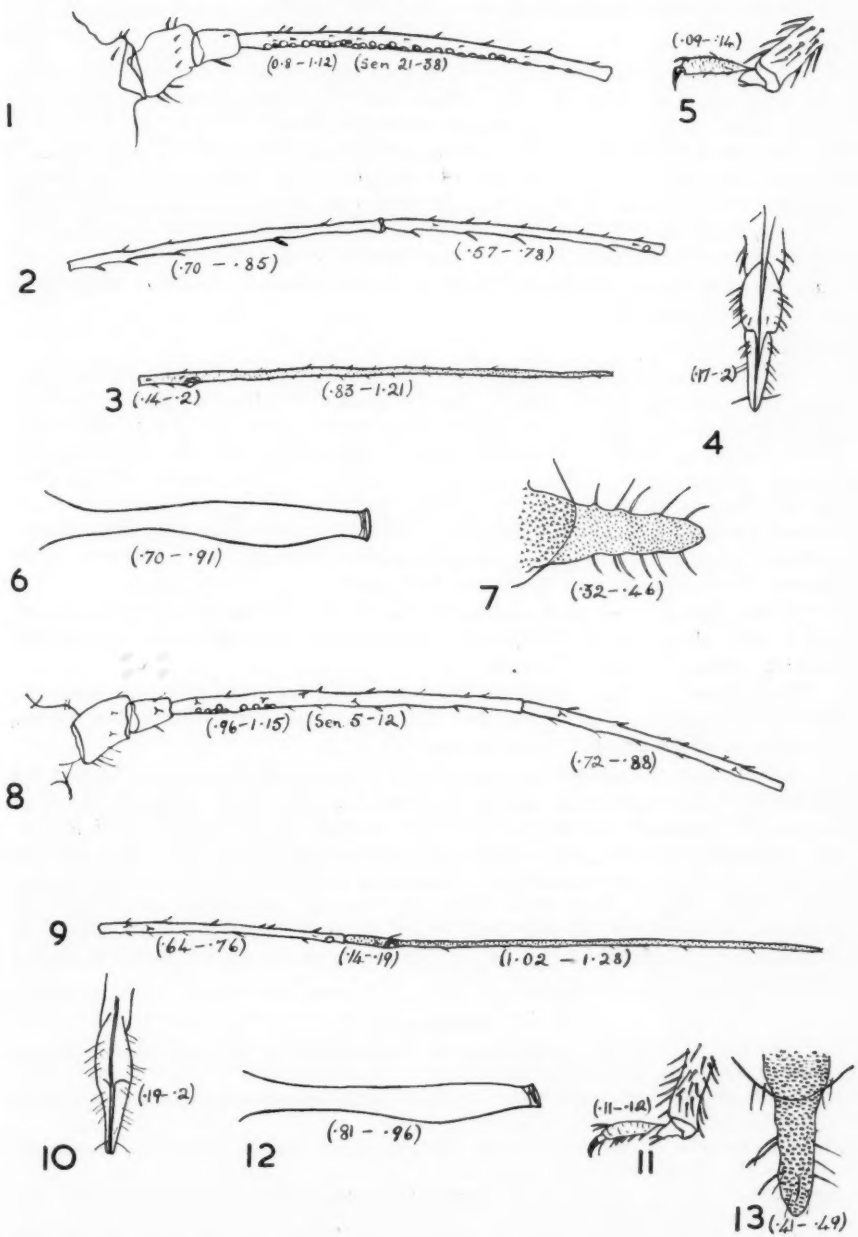
Through the kindness of Dr. R. Stace-Smith of the Canada Department of Agriculture, Plant Pathology Laboratory, Vancouver, B.C., I have been able to collect and examine specimens of a species of *Amphorophora* occurring on Thimbleberry (*Rubus parviflorus*) in British Columbia. This species, as well as showing morphological differences which separate it from all described species, differs also from them ecologically and in its ability to transmit certain *Rubus* viruses. (Stace-Smith, in press). Professors M. A. Palmer and George F. Knowlton have both seen some of this material and have given it as their opinion that it cannot be placed among the known species of *Amphorophora*. It is therefore described here as a new species.

Amphorophora parviflori n.sp.

Alate vivipara

Colour pale green with a darker green median line usually visible dorsally on the abdomen. Ventral surface of thorax and abdomen of a pale green and covered with a waxy powder. Wings clear without dusky apical spot, veins showing no dark borders; body 3.08 - 4.26 mm. long; 1.2 - 1.82 across abdomen; width of head across eyes .65; ocular tubercle present, antennae, total length, 3.52 - 4.32; III, .80 - 1.12 with 21 - 38 circular sensoria arranged more or less linearly along the entire length of the segment; IV. .70 - .85; V, .57 - .78; VI, .14 - .20 plus .83 - 1.21; rostrum, reaching to second coxae, IV and V .17 - .20; hind tibiae, 2.62 - 3.29, dusky distally; hind tarsi, .09 - .14; cornicles pale with slight striations just below the flange, length .70 - .91, maximum width .08 - .11, minimum width .04 - .06; cauda, length .32 - .46 with 5 pairs of lateral hairs.

Type: Collected on *Rubus parviflorus* Nutt., at Vancouver, B.C., Canada, July



FIGS. 1-3. *Amphorophora parviflori* n.sp. 1-7, Alate ♀; 8-13, Apterous ♀.

15th, 1956 (R. Stace-Smith). Type slide has been deposited in the Canadian National Collection; paratype in the author's collection.

Apterous vivipara.

Colour pale green, body 3.37 - 3.34 mm. long; width across abdomen 1.61 - 2.0; head across the eyes .60 - .65, ocular tubercle present; frontal tubercles distinct; antennae, pale becoming somewhat darker distally, total length 3.85 - 4.44; III .96 - 1.15 with 5 - 12 circular senoria confined to the basal half; IV, .72 - .88 without sensoria; V, .64 - .76; VI, .14 - .19, plus 1.02 - 1.28; rostral IV plus V dusky, .19 - .20; hind tibiae, 2.8 - 3.24, dusky at distal extremity; hind tarsi, .11 - .12; cornicles pale, slight striations just below flange, length .81 - .96, maximum width .09, minimum width .06; cauda pale, length. 41 - .49.

Paratypes: on *Rubus parviflorus* Nutt., at Vancouver, B.C., Canada, August 3rd, 1956 (R. Stace-Smith).

Discussion

D. Hille Ris Lambers (1949) states that Mason's genus *Amphorophora* contains many species which should not be placed in *Amphorophora* Buckton. *Amphorophora* as regarded by Mason (4) covers at least the genera *Amphorophora* Buckton, *Delphiniobium* Mordvilko, *Masonaphis* H.R.L., *Hyperomyzus* Börner, *Wohlgreniella* H.R.L., *Megourella* H.R.L., and *Oestlundia* H.R.L., Hille Ris Lambers in the same paper provides a key for the separation of these and related genera. The species described here is, according to this key, an undoubted member of the genus *Amphorophora* Buckton. It is however quite distinct from all European species of that genus.

Using Mason's key alate specimens run to *A. cicutae* Shinji while apterae run to near *A. amurensis* Mordvilko. Comparisons with the fuller descriptions however reveal distinct differences.

In Palmer's (5) key the alate form runs to *A. pawtincae* Hottes; however, detailed comparison again reveals that differences exist between the two species, for example in the length of the antennae.

In the key of Knowlton and Allen (3) it runs to *A. tigiwatensa* Hottes but differs from that species in having no border to the wing veins, the body is longer, the antennae shorter, the cornicles shorter and rostral IV + V longer. *A. rubitoxica* Knowlton also runs to *A. tigiwatensa* in this key. *A. parviflori* differs from *A. rubitoxica*, however, in having a longer body, veins not dusky, hind tibiae longer, hind tarsi somewhat shorter and cornicles longer. In addition, *A. parviflori* has only been found on *Rubus parviflorus*, on which *A. rubitoxica* is not found and it does not produce lesions on the leaves of *Rubus occidentalis*.

References

(1) Hille Ris Lambers, D. Contributions to a Monograph of the Aphididae of Europe, IV, Temminckia, 8, 224-242, 1949.

(2) Knowlton, G. F. A new black raspberry aphid, Canadian Entomoligist, LXXXVI, 235-236, 1954.

(3) Knowlton, G. F. & Allen, M. W. Amphorophora Studies, Canadian Entomologist, LXXVII, 111-112, 1945.

(4) Mason, P. W. A revision of the insects of the aphid genus *Amphorophora*, U.S. Nat. Mus. Proc., 67, 1-92, 1925.

(5) Palmer, M. A. Aphids of the Rocky Mountain Region, 229-246, The Thomas Say Foundation, Vol. 5, 1952.

(6) Stace-Smith, R. Studies on *Rubus* virus diseases in British Columbia, V. Thimbleberry Ringspot. Canadian Journal of Botany, 36, 385-388, 1958.

Life-History and Ecology of *Hylemya planipalpis* (Stein) (Diptera: Anthomyiidae), a Root Maggot Attacking Radish in Manitoba[1]

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Introduction

Root maggots infest radish in Manitoba to a limited extent each year. As early as 1920 Norman Criddle noted damage at Treesbank. In the Brandon area the infestations have usually been less than 10 per cent but have occasionally exceeded 20 per cent. *Hylemya planipalpis* (Stein) is the principal species.

There is little literature on this pest. Most references to root maggots on radish refer to other species. For example, Matthewman *et al.* (1950) identified the cabbage maggot, *H. brassicae* (Bouche), as the predominant species on radish at Ottawa whereas *H. cilicrura* (Rond.) and *H. trichodactyla* (Rond.) were given secondary importance. *H. brassicae* has not yet been reported in Manitoba. In California Essig (1915) stated that *Phorbia planipalpis* (= *H. planipalpis*) was present but not the cabbage maggot. Brooks (1951) reported *H. planipalpis* to be the major root maggot pest of radish in the Prairie Provinces of Canada.

This paper is based on work completed at Brandon, Manitoba in 1953 and 1954 and a few additional observations made in 1955 and 1956.

Distribution

H. planipalpis is found throughout western North America. It has been reported in the four western provinces of Canada by J. F. McAlpine, Ottawa (in litt.). H. C. Huckett, Riverhead, N.Y. (in litt.) has records from Alaska, Yukon Territory, the Northwest Territories, and the states of California, Colorado, Idaho, Montana, Oregon and Washington in the United States. It has also been noted in Mexico by C. W. Sabrosky, Washington, D.C. (in litt.).

Materials and Methods

Radish seedings were made about every two weeks during the growing season. Samples were taken at intervals of one to two weeks and carefully examined for root maggot eggs and larvae. Larvae thus obtained were reared in the laboratory on radish slices in Petri dishes. All flies were identified with keys prepared by Brooks (1951) and many of these determinations were checked by him.

To determine other host plants, maggots were reared from cabbage, Chinese cabbage (*Brassica chinensis* L.) and various wild Cruciferae near vegetable gardens. Also, adults were trapped in emergence cages set up in fields in which rutabagas had been grown the previous year.

The spring emergence of adults was recorded mainly by rearing in an insectary. Puparia were collected from laboratory rearings and from the field in the fall and placed in shallow trenches in soil or in a refrigerator at 40°F. to overwinter. In the spring they were recovered and placed in moist sand in paper cartons. A hole was cut in the side of the carton to fit a small screw-cap vial. Emerging flies were attracted to the light and collected in the vial.

The longevity of flies was determined in the insectary in lantern chimneys placed over a Petri dish containing a layer of plaster of Paris covered by dark green blotting paper. The top of the chimney was covered by a layer of

[1]Contribution No. 12 from the Canada Department of Agriculture Research Laboratory, Winnipeg, Manitoba. Portions of this paper were used in a thesis submitted as partial fulfilment for the Master of Science degree at Iowa State College, Ames, Iowa.

cheesecloth. Water was added frequently to keep the blotting paper moist. Two or three drops of a honey-yeast-water mixture were placed on the cheesecloth daily as food. Survival was poor, especially during hot, dry days.

Oviposition data for individual flies was obtained under fresh radish slices placed on the floor of the lantern-chimney cages.

Larvae were obtained from eggs incubated in the laboratory and they were transferred to thin radish slices for rearing singly in Petri dishes. They were examined daily. Very thin slices of radish were most suitable for this purpose as the small larvae could then be found quickly with a minimum amount of handling. The date on which an exuvia was found indicated the end of a larval instar.

Larvae which had been individually reared and others obtained from mass collections were used to determine the length of the pupal period. The puparia were reared in the laboratory in moist sand in glass-topped metal tins. Flies were collected daily for identification.

Particular note was made of the presence of parasites in all field collections of larvae and puparia. In addition, puparia of *Hylemya* spp. were collected and sent to the Entomology Laboratory, Belleville, Ontario to be examined for parasites.

The presence and relative abundance of potential egg predators was ascertained by pitfall traps made of inverted metal cones about one foot in diameter which were sunk into the ground to soil level close to radish plants. Carabid beetles obtained were identified by the Systematic Unit, Division of Entomology, Ottawa. The number of eggs eaten by individual predators was determined by offering them eggs of *H. planipalpis* in Petri dishes in the laboratory.

The presence of micro-organisms in puparia from which flies had failed to emerge was checked by G. E. Bucher, insect pathologist, now at Belleville, Ontario.

Results and Discussion

Field infestations

H. planipalpis adults were scarce during May and June. Usually eggs were not observed in the field until about the second week of June, at the same time that maggots were found. Eggs were not abundant until the second generation of flies started to oviposit in mid-July or early August.

Eggs were laid just below soil level, next to the radish root. Usually there were one to three eggs on a single radish but occasionally as many as 20 were found. At times, single eggs were found on the leaf petioles and often when these eggs hatched the larvae would burrow through the top of the crown into the root.

The percentage of maggot-infested radish in field plots varied greatly from year to year. In some years, the infestation remained below 10 per cent in June and July and rose to a high level in August. In 1954 and 1956, 80 to 90 per cent of the radish examined in late August were infested. But, in 1953 and 1955, the infestation did not exceed 25 per cent at any time during the season.

Because root maggots are difficult to identify in the larval stage they were reared to adults for determination. Four species were obtained and their frequency of occurrence is given in Table I. Brooks (1951) lists *H. planipalpis* as a primary phytophagous pest but states that *H. cilicrura, Muscina stabulans* (Fall.) and *M. assimilis* (Fall.) may cause root damage only under certain conditions.

TABLE I

Numbers of root maggots of the genera *Hylemya* and *Muscina* reared from radish in 1953–1956

	H. planipalpis	*H. cilicrura*	*M. stabulans*	*M. assimilis*
1953	47	12	0	0
1954	12	10	0	0
1955	6	1	0	0
1956	6	5	10	4
Total	71	28	10	4

Host plants

Radish is the principal host plant of *H. planipalpis*. Keifer (1931) has reported it from cabbage and turnips in California. H. C. Huckett (in litt.), who compiled records for North America, recorded it from cauliflower, brussels sprouts and *Brassica campestris* L. Brooks (1951) has reported grey tansy mustard, *Descurainia richardsonii* (Sweet) Shultz, as another host of this species in Canada.

The occurrence of *H. planipalpis* on cabbage and rutabagas was not confirmed. During a five year period more than 1,000 *Hylemya* spp. flies were taken in emergence cages in old rutabaga fields at Brandon, but no *H. planipalpis*. Nor were any reared from cabbage.

H. planipalpis was taken from two previously unreported hosts. Large numbers of root maggot eggs and larvae were found on Chinese cabbage near the end of July in 1954. Many of them were collected and reared; most of the flies obtained were *H. planipalpis*. On another occasion, three root maggots were found on common peppergrass, *Lepidium densiflorum* Schrad. Two of them were reared and identified as *H. planipalpis*.

Life-history and seasonal history

H. planipalpis overwinters in a puparium. Spring emergence of adults extends from the last week of May to the middle of June. Most of the flies emerge in the first few days of this period.

At Brandon, Manitoba, first-generation adults emerged at the end of June or the first week in July. A peak of second-generation fly emergence in cages was observed during the first week in August of 1953. This generation of adults laid a large number of eggs in most years, giving a greatly increased maggot infestation. It was noted that the overwintering puparia were formed after the third week of August. It seems probable that there are three generations of *H. planipalpis* each year. However here is a wide overlap of generations and usually all stages are present throughout the growing season.

Data on the oviposition and longevity of five *H. planipalpis* females are given in Table II. These females were caged individually in lantern-chimney cages and were kept supplied with a male. Longevity records were also kept for 13 other females. The maximum life time was found to be 40 days and the average 16.0 days. Longevity of 10 male flies ranged up to 30 days and averaged 12.1 days. No significant increases in oviposition were noted when the number of males or females per cage was increased.

One female, which was supplied with a male during the pre-oviposition period only, laid 109 fertile eggs. An unmated female laid 28 eggs.

TABLE II

Number of days oviposition and life of five *H. planipalpis* females

Specimen No.	Preoviposition period	Oviposition period	Life	No. of eggs
1.	25	15	40	53
2.	4	13	28	56
3.	3	16	32	52
4.	—	—	31	0
5.	12	8	23	44
Mean	11.0	13.0	30.8	41.0

Mortality was not high among larvae reared individually in the laboratory despite the handling. The lengths of the various life stages are given in Table III. The total developmental period from egg to adult averaged 31.7 days for the five specimens which survived to the adult stage. For another group of 44 specimens, the pupal period ranged from 10 to 17 days and averaged 12.7 days. In three cases the pupal period lasted from 21 to 30 days. No differences were found between sexes. The egg, larval and pupal periods recorded are slightly shorter than those noted for *H. brassicae* by Gibson and Treherne (1916). These workers reported 2 to 10 days for the egg stage, 19 to 32 days for the larval period, and 15 to 18 days for the pupal period.

Natural control

Two species of parasites were reared from mass collections of *H. planipalpis* and *H. cilicrura*. These were the hymenopteron *Trybliographa rapae* (Westw.) and the staphylinid beetle *Aleochara bilineata* Gyll. The former species is a larval parasite and has been described by Wishart and Monteith (1954); the latter species is a pupal parasite. The occurrence of parasites in collections was sporadic; parasitism rarely exceeded 20 per cent.

Wishart (1957) surveyed the parasites of *Hylemya* spp. in Canada. Of 56 *H. planipalpis* puparia submitted to him from Manitoba in 1951, 10.5 per cent were parasitized by *A. bilineata* and 1.9 per cent by *T. rapae*. Wishart suggests that the scarcity of *H. planipalpis* early in the season in Manitoba may be the

TABLE III

Duration (in days) of life stages of *H. planipalpis*

Life stage	Range	Mean	No. of specimens
Egg	2 to 3	2.1	103
First stage larva	2 to 4	3.1	18
Second stage larva	2 to 5	3.5	13
Third stage larva	8 to 13	10.0	9
Pupa	12 to 16	13.0	5
Total, egg to adult	26 to 41	31.7	

controlling factor which results in a low percentage of parasitism of other *Hylemya* species later in the year.

Pitfall traps yielded large numbers of possible or potential predators. The two most abundant species were the carabid beetles *Bembidion quadrimaculatum oppositum* Say and *Agonoderus comma* Fab. The identity of the latter species was confirmed by Carl Lindroth, Lund, Sweden. Frequently a total of 15 predators were taken in one trap during a 24-hour period. The former species was particularly abundant among radish infested with root maggot eggs. In the laboratory both species readily ate *H. planipalpis* eggs.

No specific evidence of a disease pathogen was found by G. E. Bucher in a collection of 18 puparia containing dead pupae. The variability of the time of death, the variability of symptoms and the organisms present suggested that death was due to some physiological cause.

Summary

Hylemya planipalpis (Stein) is found over most of western North America. In Manitoba it is the principal maggot pest of radish. It was reared from common peppergrass and Chinese cabbage but was not found on cabbage or rutabaga.

The insect overwinters in a puparium. Spring adults start to emerge about the last week of May. Three generations of *H. planipalpis* each year are possible but frequently all stages occur at the same time. The preoviposition and oviposition periods of caged females averaged 11.0 and 13.0 days respectively. They laid an average of 41.0 eggs. Female flies lived for an average of 16.0 days, males for an average of 12.1 days. The difference was not found to be statistically significant. Individuals reared singly in the laboratory spent 2.1 3.1, 3.5, 10.0 and 13.0 days in the egg, first, second and third larval instars and pupal period, respectively.

Two species of parasites, *Trybliographa rapae* and *Aleochara bilineata*, were reared from *H. planipalpis;* parasitism was usually below 20 per cent. The carabid egg predators, *Bembidion quadrimaculatum oppositum* and *Agonoderus comma*, were often abundant and their activities apparently reduced the root maggot infestation in some instances. No evidence of disease micro-organisms was found.

Acknowledgements

Preliminary investigations in this project were conducted in 1952 by Mr. T. V. Cole of the Entomology Field Station at Brandon. I am particularly indebted to him since he suggested many of the approaches and devised several of the methods. Dr. R. D. Bird, now at the Canada Agriculture Research Laboratory, Winnipeg, also contributed greatly by suggesting lines of research and reading the manuscript. Dr. J. H. Lilly, Professor, Iowa State College, Ames, Iowa, served as adviser while some of the early material was being prepared for a thesis.

References

Brooks, A. R. 1951. Identification of the root maggots (Diptera: Anthomyiidae) attacking cruciferous garden crops in Canada, with notes on biology and control. Canadian Ent. 83: 109-120.

Essig, E. O. 1915. Injurious and beneficial insects of California. 2nd edition. Sacramento, California, State Comm. of Horticulture pp. 336-339.

Gibson, Arthur, and R. C. Treherne. 1916. The cabbage root maggot and its control in Canada, with notes on the imported onion maggot and the seed-corn maggot. Canada, Dept. Agr. Ent. Br. Bull. 12.

Keifer, H. H. 1931. Miscellaneous insect notes and descriptions. California, Dept. Agr. Mo. Bull. 20: 249-250.

Matthewman, W. G., A. W. Rathwell, and J. P. Lachaine. 1950. Notes on the species of root maggots damaging onions, cabbage, and radish at Ottawa in 1948. Canadian Ent. 82: 12-16.

Wishart, George. 1957. Surveys of parasites of *Hylemya* spp. (Diptera: Anthomyiidae) that attack cruciferous crops in Canada. Canadian Ent. 89: 450-454.

Wishart, George, and Elizabeth Monteith. 1954. *Trybliographa rapae* (Westw.) (Hymenoptera: Cynipidae), a parasite of *Hylemya* spp. (Diptera: Anthomyiidae). Canadian Ent. 86: 145-154.

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Humidity Reactions of *Melanoplus bivittatus* (Say) and *Camnula pellucida* (Scudd.) (Orthoptera: Acrididae): Reactions of Starved and of Moulting Grasshoppers[1]

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Previous work (11) showed that two species of grasshoppers, *Melanoplus bivittatus* (Say) and *Camnula pellucida* (Scudd.), normally prefer a dry atmosphere. The present paper deals with the effects of starvation and of moulting on the humidity reactions of these species.

Materials and Methods

To test the effect of starvation on humidity reactions, adults of the two species from laboratory-reared cultures were used. Each adult was placed in a separate, cylindrical, plastic-screen cage, which was eight inches long, two inches in diameter, and corked at both ends, The caged insects, without food or water, were placed for four or five days, or until death, in racks in a rearing room maintained at 30 $\pm$ 0.5°C. and 40 $\pm$ 1 per cent relative humidity. At intervals triplicated samples of ten adults, of one species and sex, were removed from the cages to test their reactions to alternative humidities of 0 and 90 per cent in an olfactometer (11).

Changes in total live weight, water content and fat content were determined, at the time of each test, from triplicated samples of three adults of the same species and sex, and starved for the same period, as those being tested in the olfactometer. The three adults of each sample were decapitated, weighed, and placed in a glass vial in an oven maintained at 105°C. After eight hours they were removed, allowed to cool in a desiccator, and weighed again. Then the fat was extracted from the sample with low-boiling-point petroleum ether in a micro-Soxhlet apparatus, and weighed.

The effect of moulting on the humidity reactions of the two species was tested during the first and fifth nymphal moults of *M. bivittatus* and the second nymphal moult of *C. pellucida*. One sample of 20 nymphs of each of the above instars was exposed to various alternative humidities(see Table III) in an olfactometer (11) at irregular intervals after cessation of feeding and activity indicated the approach of moulting, until it was completed and normal activity was resumed.

Results

Within a few hours after food and water were withheld, adult grasshoppers showed a decreased preference for the dry environment (Tables I and II). This

[1]Contribution No. 9, Canada Department of Agriculture Research Laboratory, Saskatoon, Saskatchewan; from a thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Illinois, 1954.
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TABLE I

Changes in live weight, water content, fat content, and humidity reactions of *M. bivittatus* during four or five days of starvation at 30°C. and 40 per cent relative humidity

Hours starved	Percentage of normal			Index of reaction*
	Live weight	Water	Fat	
Males				
0	100.0	100.0	100.0	24±2.1†
10	98.5	96.6	97.4	15±2.1
25	99.1	96.9	91.8	10±6.6
35	83.3	79.0	66.5	8±2.0
55	79.9	74.8	66.2	−6±13.2
70	75.4	68.4	73.9	−5±10.1
85	72.2	65.2	63.1	−2±5.3
95	66.2	59.3	53.8	−13±1.6
Females				
0	100.0	100.0	100.0	23±3.2
10	93.3	94.0	72.8	11±3.0
25	72.2	71.5	66.3	9±5.3
30	76.0	75.0	69.8	2±4.9
35	73.7	72.8	65.5	−1±5.3
50	76.9	75.7	67.1	−.6±4.1
60	58.4	55.5	44.6	−8±1.0
75	59.7	54.9	52.4	−9±3.7
100	44.8	41.6	42.5	−9±8.5
120	50.9	45.0	27.3	−6±4.1

*Mean excess percentage of grasshoppers preferring 0 per cent to 90 per cent relative humidity.
†Standard deviation.

decline continued for the next two days until no preference was shown. Thereafter the high humidity was preferred, but this preference was not as pronounced as that of normal grasshoppers for dry air. Total live weight, water content, and fat content, respectively, declined daily by about 14, 12, and 10 per cent of normal.

The nymphs preferred the drier of two atmospheres until about 20 hours before moulting (Table III). Thereafter a preference for the moist atmosphere developed gradually and was maintained during the moulting process, as well as for a few hours after ecdysis was completed. About 12 hours after moulting the grasshoppers once again preferred a dry environment.

Discussion

Presumably to compensate in part for the loss of water during fasting, the insects became hygropositive. This reversal of the response to humidity during starvation is similar to that exhibited by other normally 'dry preference' insects (1, 4, 5, 7, 10, 12).

TABLE II

Changes in live weight, water content, fat content and humidity reactions of *C. pellucida* during four days of starvation at 30°C. and 40 per cent relative humidity

Hours starved	Percentage of normal			Index of reaction*
	Live weight	Water	Fat	
Males				
0	100.0	100.0	100.0	30±1.6†
5	94.3	93.8	96.4	24±3.1
15	94.2	92.6	96.7	14±5.6
25	82.0	81.1	75.3	11±3.1
40	86.2	83.2	85.2	1±2.7
60	85.9	81.5	83.2	−2±1.2
80	73.9	66.8	62.2	0.2±2.6
95	60.9	54.2	48.4	−4±3.6
100	50.7	45.6	33.6	−11±4.2
Females				
0	100.0	100.0	100.0	30±1.6
5	93.4	93.8	94.1	22±4.8
15	98.5	98.3	91.2	16±2.6
30	99.1	90.8	106.5	10±6.0
35	83.7	81.4	83.2	2±2.3
55	84.6	79.5	79.9	0±1.4
80	75.5	72.9	38.1	−2±4.1
95	67.7	64.6	28.6	−6±4.7
100	70.9	65.1	31.9	−12±5.5

*Mean excess percentage of grasshoppers preferring 0 per cent to 90 per cent relative humidity.
†Standard deviation.

During the four or five days of starvation the grasshoppers lost 45 per cent of their body water before death. Though they were kept at 40 per cent relative humidity the loss of water was similar to that incurred by *Chortophaga viridifasciata* (DeG.) when kept at 0 to 5 per cent relative humidity (8). It was also similar to that in the 'pre-mortal' phase of starvation in mammals (2). The decrease in body fat approximated that reported for several other insects when starved (9, 14).

The reversal of the humidity reaction during the moulting process is not remarkable in view of the physiological hyperactivity involved in that process (3, 6, 13, 15).

The new cuticle is readily permeable to water until shortly before moulting but water loss is normally prevented by the outer layers of the old cuticle (13). However, on several occasions in the field when the air was hot and very dry, the author observed nymphs of *C. pellucida* that died when they were unable to

TABLE III
Humidity reactions of *M. bivittatus* and *C. pellucida* before, during, and after moulting

Instar, and hours pre- or post-moult	Alternative relative humidities	Index of reaction*
M. bivittatus, first instar		
18 hr. pre-moult	45 : 60	13.0
4 hr. pre-moult	30 : 75	6.0
3 hr. pre-moult	30 : 75	−0.5
1 hr. pre-moult	30 : 75	−8.0
at moulting time	15 : 45	−22.0
1 hr. post-moult	14 : 45	−13.0
M. bivittatus, fifth instar		
24 hr. pre-moult	0 : 45	22.5
23 hr. pre-moult	0 : 45	21.0
13 hr. pre-moult	0 : 45	−18.5
1 hr. pre-moult	0 : 45	−8.0
12 hr. post-moult	0 : 45	20.0
C. pellucida, second instar		
24 hr. pre-moult	0 : 60	44.0
23 hr. pre-moult	0 : 60	39.5
22½ hr. pre-moult	0 : 60	28.5
22 hr. pre-moult	0 : 75	1.5
19 hr. pre-moult	0 : 75	−10.5
at moulting time	0 : 75	−24.0
12 hr. post-moult	0 : 75	4.5
21 hr. post-moult	0 : 75	29.5

*Mean excess percentage of grasshoppers preferring the lower to the higher relative humidity

rid themselves of the pro-nymphal skins or the exuviae. Presumably the rapid evaporation of the moulting fluid prevented normal ecdysis. Thus the preference of the nymphs for a moist environment at moulting time is a means of preventing excessive evaporation of the moulting fluid.

In areas where *C. pellucida* nymphs are found, often more than 100 per square foot, it is common to find exuviae piled in dense clusters under succulent weeds, where the microclimate is more humid than in less heavily vegetated areas. In these instances the massing of the nymphs when moulting is assumed to be a manifestation of their preference for a moist atmosphere.

Summary

The humidity reactions of starved adults of *M. bivittatus* and *C. pellucida* were tested in an olfactometer over a four- or five-day starvation period. A

reduction in the intensity of the normal dry preference was observed after 24 or 36 hours of fasting. A wet preference, exhibited after 3 or 4 days of starvation, was maintained until death.

Nymphs of both species showed a normal preference for dry air until about 20 hours before moulting. Thereafter a preference for the moister atmosphere became evident and was maintained throughout ecdysis and for a few hours following the moulting act. A preference for dry air was evident again about 12 hours after moulting was completed.

After 72 to 96 hours of starvation at 30°C. and 40 per cent relative humidity, the grasshoppers lost an average of 40 per cent of their normal live weight, 45 per cent of the body water and 57 per cent of the body fat.

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References

1. Bentley, E. W. The biology and behaviour of *Ptinus tectis* Boie (Coleoptera, Ptinidae), a pest of stored products. V. Humidity reactions. *J. Expt. Biol.* 20: 152-158. 1944.
2. Chambers, W. H. Undernutrition and carbohydrate metabolism. *Physiol. Rev.* 18: 248-296. 1938.
3. Gunn, D. L. Oxygen consumption of the cockroach in relation to moulting. *Nature* 135: 343. 1935.
4. Gunn, D. L., and C. A. Cosway. The temperature and humidity relations of the cockroach. V. Humidity preference. *J. Expt. Biol.* 15: 555-563. 1938.
5. Krijgsman, B. J. Reizphysiologische Untersuchungen an blutsaugenden Arthropoden im Zusammenhang mit ihrer Nahrungswahl. I Teil: *Stomoxys calcitrans*. *Zeitschr. vergl. Physiol.* 11: 702-729. 1930.
6. Lafon, M. Recherches sur le cycle de la chitine chez quelques coleoptères. *Arch. Zool. Exp. et Gén.* 83: 58-70. 1943.
7. Lees, A. D. The sensory physiology of the sheep tick, *Ixodes ricinus* L. *J. Expt. Biol.* 25: 145-207. 1948.
8. Ludwig, D. The effect of different relative humidities on respiratory metabolism and survival of the grasshopper *Chortophaga viridifasciata* DeGeer. *Physiol. Zool.* 10: 342-351. 1937.
9. Mellanby, K. The effect of atmospheric humidity on the metabolism of the fasting mealworm, (*Tenebrio molitor* L., Coleoptera). *Proc. Roy. Soc.*, B, 111: 376-390. 1932.
10. Perttunen, V. Seasonal change in the humidity reaction of the common earwig, *Forficula auricularia*. *Nature* 170: 209-210. 1952.
11. Riegert, P. W. The humidity reactions of *Melanoplus bivittatus* (Say) and *Camnula pellucida* (Scudd.) (Orthoptera: Acrididae): Reactions of normal grasshoppers. *Canandian Ent.* In press.
12. Roth, L. M., and E. R. Willis. The effects of desiccation and starvation on the humidity behavior and water balance of *Tribolium confusum* and *Tribolium castaneum*. *J. Expt. Zool.* 118: 337-361. 1951.
13. Wigglesworth, V. B. The physiology of the cuticle and of ecdysis in *Rhodnius prolixus;* with special reference to the function of the oenocytes and of the dermal glands. *Quart. J. Micr. Sci.* 76: 269-318. 1933.
14. Wigglesworth, V. B. The principles of insect physiology. 3rd ed. *Methuen & Co. Ltd.*, London.
15. Wigglesworth, V. B. The insect cuticle. *Biol. Rev.* 23: 408-451. 1948.

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Dispersal of the Pine Needle Scale, *Phenacaspis pinifoliae* (Fitch), (Diaspididae: Homoptera)[1]

C. E. Brown[2]

Introduction

The dispersal of the pine needle scale has long been a problem to entomologists. Although its transfer on nursery stock has been accepted as a means of dispersal, the method of its spread from tree to tree in a localized area has not been investigated previously. There are two stages in its development when it is able to move about by its own volition: the crawler or first instar nymphs wander for short distances on the twigs of the host tree and the adult males move about freely. Effective spread of this scale occurs only in the crawler stage. Phoresy is unlikely because nymphs have extreme difficulty in crossing small gaps such as would be encountered in transferring from a needle to an insect or bird and parent scales do not secrete substances attractive to carriers as described by Mahdihassan (1933) for some lac-insects. Because of the limited motility of the first instar nymphs, dissemination by wind required investigation.

Synoptic Review

Literature on the dispersal of scale insects is very meagre. Riley (1873) and Le Baron (1871) believed that the females instinctively travelled to the newest growth in order that the young would have the most suitable feeding place, or so that they and their eggs would not be borne to the ground when the older needles fell. They reasoned that the males fed for such a short time that their feeding site was of little importance, hence the instinct to migrate to the new growth was not developed. Riley (1887) gave an account of the distribution of the cottony-cushion scale, *Icerya purchasi* Maskell, in which he concluded that this scale was spread by wind, water, birds, animals, and flying insects, but primarily by transportation on nursery stock. He believed that wind was an important carrier, especially during the violent storms which occurred when the crawlers were active. Wellington (1945) concluded that short-range distribution of insects by wind was important but that long-range distribution was largely ineffective. Rabkin and Lejeune (1954) showed that nymphs of the pine tortoise scale, *Toumeyella numismaticum* (Pettit and McD.), could be carried up to three miles by wind but thought that the establishment of wind-borne infestations beyond that distance was unlikely. Strickland (1950), working on wind dispersal of coccids in Africa, concluded that wind was not an important means of distribution. He based his conclusions on the small number of coccids found in his traps compared with the numbers of other insects taken.

Materials and Methods

An experiment to determine the distance walked by nymphs of the pine needle scale was conducted on Scots pine at the Forest Nursery Station, Indian Head, Sask., in 1951. A wind tunnel experiment was performed in the Forest Biology Laboratory at Indian Head in 1951. Outdoor experiments to determine the distances nymphs could be carried by the wind were conducted in the Crowsnest Pass, Alta., in 1956 and 1957. Naturally occurring infestations on lodgepole pine were used as a source of nymphs for both experiments.

The distance walked by the progeny of isolated females of the pine needle scale was determined by measuring the distance from the parent female down

[1]Contribution No. 472, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada; based on part of a thesis presented to the Faculty of the Graduate School of the University of Minnesota in partial fulfilment of the requirements for the degree of Master of Science.

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the needle to the twig, along the twig and up the needle to the settled nymph. Lightly infested Scots pine were chosen so that the progeny of each parent could be distinguished from the others. The trees selected were in an isolated, sheltered location and contamination by wind borne nymphs was unlikely. Since no females were present above those chosen there was no contamination by nymphs dropping from above.

A wind tunnel, 1 foot square and 8 feet long, was used to determine the distance crawlers could be carried by wind. It was constructed from sheets of tempered masonite with the smooth side inward. Constant speed fans were placed at each end and their position adjusted until a uniform air speed throughout the tunnel was obtained (2.5 mph.). Twigs on which nymphs were emerging were placed at the entrance of the tunnel, and the fans were operated continuously for 48 hours. The distance nymphs were carried was determined by placing a 9-foot long strip of paper on the floor of, and extending from, the tunnel. Bands of petroleum jelly were painted across the paper at intervals of 6 inches and the number of nymphs caught on each band was recorded.

The traps used to determine both the inter and intra-stand spread of the pine needle scale were of brown Kraft paper painted with melted petroleum jelly. These papers were 6 x 6 inches or 6 x 18 inches in size and were tacked to plywood backing slightly larger than the paper size. The traps were nailed about 3 feet from the ground on small posts. After exposure the sticky side of the paper was covered with a thin sheet of plastic (saran wrap). The plastic sheet was left on the trap during examination since it did not impair visibility and greatly simplified handling.

Traps to determine the intra-stand spread of the pine needle scale were set out in 1956. The traps were placed around a clump of infested lodgepole pine surrounded by aspen poplar and separated from other infested pine by at least 200 feet. These traps were placed under the outer branches of the outside trees and at distances of 10, 20, and 30 feet from the outer branches.

The second series of traps to determine the inter-stand distance which nymphs could be carried was placed in a down-wind direction from the eastern edge of a heavily infested stand in the Crowsnest Pass. The source of infestation was on the southwestern side of a wide valley, and the traps were placed down that side of the valley, in the valley bottom and up the other side. The last trap (1-3/4 miles) was at almost the same elevation as the source of infestation, while the others were considerably lower.

The long period over which the eggs may hatch (up to 2 weeks) and the great variation in wind speed and turbulence which occurs while temperature conditions are favourable for hatching made it impossible to correlate wind speed with the transport of nymphs to the traps. During the time when the traps were out to determine the intra-stand spread of the scale the wind speed varied from 0 to 48 mph., the maximum temperature was 87°F., the minimum temperature was 35°F., and several thundershowers passed through the area. While the second series of traps was in operation the wind speed varied from 0 to 35 mph., the maximum temperature was 84°F., the minimum temperature 33°F., and thundershowers occurred.

Results

The selection of a feeding site must be made during the first few days of the insect's life because the legs are lost when the first nymphal skin is cast. Cumming (1953) found that 70 per cent of the females were on the new growth of white spruce twigs while 99 per cent of the males were on the old growth.

TABLE I

The distance travelled from the parent female by the male and female nymphs of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), on Scots pine at Indian Head, Sask., in 1951 and 1952

	Parent female	Male nymphs		Female nymphs	
		Number	Average distance travelled	Number	Average distance travelled
1951	1	7	3.8 cm.	24	8.2 cm.
	2	6	2.6 cm.	13	9.6 cm.
	3* 4	25	2.9 cm.	34	10.7 cm.
	5	2	1.5 cm.	16	14.2 cm.
	6	6	1.0 cm.	16	11.9 cm.
	Total	46	2.6 cm.	103	10.8 cm.
1952	1	9	2.4 cm.	27	13.2 cm
	2	7	2.6 cm.	9	9.9 cm.
	3	11	1.5 cm.	17	13.0 cm.
	4	8	2.7 cm.	14	9.2 cm.
	5	10	2.4 cm.	20	11.6 cm.
	6	5	3.0 cm.	11	12.1 cm.
	7	12	3.3 cm.	21	9.5 cm.
	Total	62	2.6 cm.	119	11.3 cm.

*Unable to separate progeny.

Both male and female nymphs settled on needles of Scots pine which were at least one year old because the motile stage of this insect takes place before the new needles appear.

Table I shows the distances travelled by the progeny of thirteen parent scales. The distances given do not represent the total distance travelled by each nymph, as they undoubtedly wandered back and forth along the twig and perhaps up and down several needles before settling down. In 1951, female nymphs travelled an average of 10.8 cm. (standard deviation 5.95 calculated from raw data) while the males travelled an average of 2.7 cm. (s.d. 2.03). In 1952 females travelled 11.3 cm. (s.d. 6.07) and males 2.6 cm. (s.d. 1.45) The average distance travelled by the female nymphs was approximately four times that travelled by the male nymphs.

The possibility of spread of the pine needle scale by wind was established from the results of the wind tunnel experiment. It was found that nymphs were carried a maximum distance of 72 inches while falling through an average vertical distance of 7.5 inches when borne by a wind of 2.5 miles per hour (Table II).

According to Stephenson (1952), it can be shown that a small object with

TABLE II

The distance nymphs of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), were borne by a wind of 2.5 miles per hour and falling through a vertical distance of from 5 to 10 inches

	Distance in feet												
	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
Number of nymphs	4100	7100	4282	2875	1104	456	180	147	198	93	60	43	29

a Reynolds number of less than 100 released from rest in a uniform airstream will travel in a straight line expressed by the equation.

$$x\left(\frac{V}{VT}\right)y$$

where x = horizontal distance travelled from point of release
y = vertical distance fallen from point of release, V = horizontal wind speed, and VT = terminal velocity of object.

Using this formula, a nymph which travelled a horizontal distance of 72 inches and a vertical distance of 7.5 inches would have a terminal velocity of 0.26 miles per hour. At this speed the Reynolds number of the motion will be less than 100 if the diameter of the object is less than about one-half inch and so the above assumption appears to be justified, (Stephenson 1952). If this nymph fell from a twig 8 feet from the ground in a 40 mile per hour wind it would travel 1230 ft. These data show that nymphs can be carried considerable distances by the wind; under natural conditions vertical currents would play a very important part in the distance travelled as such currents often exceed the velocity necessary to transport these nymphs.

Confirmation of the hypothesis that pine needle scale nymphs are transported by the wind was obtained by setting up traps near infested trees.

The experiment to demonstrate intra-stand spread of the scale showed that great numbers of nymphs were transported for short distances. As shown in Table III, the largest number of nymphs were caught on the traps nearest the trees. This is in contrast to the results obtained by Rabkin and Lejeune (1954) who found that the largest numbers of pine tortoise scale, *Toumeyella numismaticum* (Pettit and McD.), were caught on traps 25 feet from the trees rather than on traps placed directly under the trees.

TABLE III

Intra-stand spread of nymphs of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), when carried by the wind under forest conditions

Distance from source	Number of crawlers per 36 square inches of trap			
	South from source	North from source	East from source	West from source
Directly below	846	3636	2556	1845
10 feet	787	—	711	1026
20 feet	566	—	513	765
30 feet	342	496	441	990

TABLE IV

Inter-stand spread of nymphs of the pine needle scale, *Phenacaspis pinifoliae* (Fitch), when carried by the wind in open conditions

	Distance from Source				
	100 yds.	350 yds.	¾ mile	1¼ mile	1¾ mile
Number of crawlers per 36 sq. in. of trap*	46.3	41.3	0.3	1.0	3.0

*Converted to trap size used in Table III.

The large number of nymphs caught on the traps under forest conditions suggested that wind might be an important factor in the spread of this insect between stands. Table IV shows that nymphs can be carried considerable distances. Where host trees are separated by distances of one to two miles it is likely that new infestations could arise from wind drifted nymphs.

The chance of new populations being established by wind-borne nymphs would decrease rapidly as the distance from the source of infestation increased; individuals would be blown farther and farther apart and the chances of males finding females would become less and less.

From these three experiments it was concluded that wind is an important factor in the spread of pine needle scale from tree to tree in a stand and from stand to stand at distances of from one to two miles. Carriage on nursery stock remains the most likely means of dispersal to widely separated locations.

Summary

Experiments designed to study the motility of the pine needle scale showed that female nymphs travel about four times farther than male nymphs. A wind tunnel was constructed to check dispersal by wind, and it was found that nymphs could be transported by air currents. Wind borne nymphs were caught on traps 1-3/4 miles from the nearest infested trees. It was concluded that wind is the most probable means of dispersal from tree to tree within a stand and that successful establishment may occur from wind-blown nymphs when distances are not too great.

Acknowledgments

The author wishes to thank A. C. Hodson, Department of Entomology and Economic Zoology, University of Minnesota, and L. O. T. Peterson, Forest Biology Laboratory, Indian Head, Sask., for their help and guidance.

Literature Cited

Cumming, M. E. P. 1953. Notes on the life history and seasonal development of the pine needle scale, *Phenacaspis pinifoliae* (Fitch) (Diaspididae: Homoptera). Canadian Ent. 85: 347-358.

Le Baron, Wm. 1871. The white pine leaf-louse. 2nd annual report on the noxious insects of the state of Illinois. p. 83.

Mahdihassan, S. 1933. Sex-ratio variability and the problem of reproduction among the lac-insects. K. Akademie van Wetenschappen, Amsterdam. 36: 343-350.

Rabkin, F. B., and R. R. Lejeune. 1954. Some aspects of the biology and dispersal of the pine tortoise scale, *Toumeyella numismaticum* (Pettit and McD.) Canadian Ent. 86(12): 570-575.

Riley, C. V. 1873. The pine-leaf scale-insect *Mytilaspis pinifoliae* (Fitch). Fifth annual report of the noxious beneficial, and other insects of the state of Missouri. p. 97.

Riley, C. V. 1887. Report of the entomologist for the year 1886. Govt. Printing Office, Washington, D.C. pp. 483-484.

Stephenson, T. C. 1952. Section Head of Aero-Dynamics of the Division of Mechanical Engineering. National Research Council, Ottawa, Canada. Personal Communication.

Strickland, A. H. 1950. The dispersal of Pseudococcidae (Hemiptera:Homoptera) by air currents in the Gold Coast. Proc. Roy. Ent. Soc. London (A) 25: 1-9.

Wellington, W. G. 1945. Conditions governing the distribution of insects in the free atmosphere. Canadian Ent. 77: 7-15, 21-28, 44-49, 69-74.

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A New *Delphinium*-Infesting Aphid (Homoptera : Aphididae)[1]

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***Kakimia robinsoni* n.sp.**

Apterous Viviparous Female

Holotype.—Dorsum of head with six blunt or slightly clavate setae. Frontal tubercles well developed, smooth, diverging, each with one long, blunt seta on dorsal surface and one or two on ventral surface. Antenna about as long as body, third segment expanded just distad of base to almost twice its basal diameter; 56 small, tubercle-like, secondary sensoria scattered along whole length of one third segment, 60 on other; one fourth segment with four secondary sensoria, the other with five; a single, large, primary sensorium near apex of each fifth segment, and one large one and five or six adjacent smaller ones near apices of basal portion of sixth segment; each small primary sensorium on sixth segment with a central papilla; all primary sensoria lacking marginal, cilia-like fimbriations. Antennal setae distinctly capitate and about equal in length to basal diameter of third segment. Lengths of antennal segments as follows: III, 0.85 mm.; IV, 0.4 mm.; V, 0.3 mm.; VI, 0.15-0.85 mm. Rostrum reaching slightly beyond middle coxae; apical segment 0.13 mm. long, with 17 slender pointed setae in addition to usual apical ones.

Dorsum of thorax with long, blunt or capitate setae on conspicuous integumentary protuberances. Meso- and meta-thoracic spiracles on membranous papillae, with deep, cylindrical atria. A large, pigmented sclerite covering whole of dorsum of prothorax; a large, perforated, pigmented sclerite on dorsum of mesothorax; metathorax with isolated, protuberant sclerites, each of which bears a blunt or a capitate seta. Blunt or capitate setae on coxae, trochanters, femora, and basal four-fifths of tibiae; pointed setae elsewhere on legs. First segments of tarsi each with three setae. Hind tibia 2.2 mm. long. Second segment of hind tarsus 0.2 mm. long.

Dorsum of abdomen with strongly protuberant, spinal and pleural sclerites, each sclerite with one or two erect, blunt or slightly capitate setae. Marginal sclerites well developed, sometimes sub-divided; each sclerite with three or four blunt or distinctly capitate setae. Marginal tubercles absent. Venter of abdomen lacking sclerites; irregular, transverse rows of slender, slightly capitate setae on each segment. Subgenital plate with two long, slender setae near anterior margin, and 13 similar but shorter setae along posterior margin. Cauda 0.25

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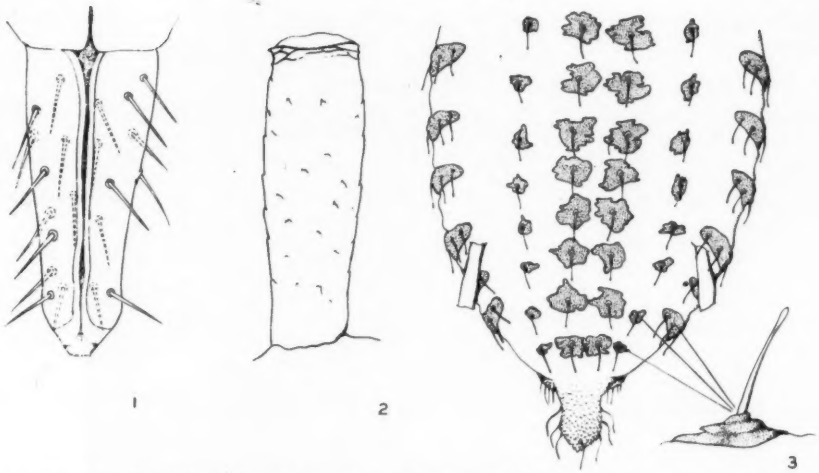

Figs. 1-3. *Kakimia robinsoni* n.sp. 1, apical segment of rostrum. 2, cornicle. 3, dorsum of abdomen of apterous viviparous female.

mm. long, somewhat spatulate; with three slender, curved setae on each side and a dorsal, preapical one. Three setose gonopophyses. Cornicles 0.25 mm. long, apical halves slightly swollen, very weakly spiculose. Spiracle weakly reniform, with a small, oval pigmented sclerite attached to anterior margins.

Integument: Fifth and sixth antennal segments with untoothed imbrications, remainder of antenna smooth or nearly so. Rostrum, dorsum and venter of head and thorax smooth. Coxae, trochanters, femora, and tibiae smooth. Second segment of each hind tarsus with untoothed imbrications. Dorsum and venter of abdomen smooth except for seventh and eighth segments which have spiculose imbrications. Subgenital and anal plates and cauda strongly spiculose.

Colour (cleared specimen on slide): Head, thorax, appendages, abdominal sclerites, and cauda light brown; apices of tibiae and antennal segments slightly darker; cornicles very light brown, slightly darker near the apices.

Length 3 mm.

Collected at Winnipeg, Manitoba, June 24, 1957 (A. G. Robinson), on *Delphinium* sp. No. 6614 in the Canadian National Collection.

Alate Viviparous Female

Paratype.—Third antennal segments with 65 and 85 secondary sensoria, fourth segments with 12 and 15, fifth segments with two and five. Length of antennal segments: III, 0.9 mm.; IV, 0.35 mm.; V, 0.325 mm.; VI, 0.15-0.9 mm. Apical rostral segment 0.175 mm. long. Wings hyaline, medius two-branched. Hind tibiae 2.25 mm. long; second segment of hind tarsi 0.175 mm. Postsiphuncular sclerite well developed, pigmented, joined to marginal sclerite of sixth abdominal segment. Some spinal sclerites narrowly fused. Length 2.5 mm. Otherwise essentially as apterous viviparous female.

Other paratypes: two apterous and four viviparous females. Data as for holotype.

Comments

This species is similar to *Kakimia wahinkae* Hottes from which it may be distinguished by the presence of secondary sensoria on the fourth antennal

segment in the apterous viviparae and on the fourth and fifth segments in the alate viviparae.

References

Doncaster, J. P. and H. L. G. Stroyan. 1952. A new subgenus and new species of aphid from Jan Mayen Island. *Ann and Mag. Nat. Hist.* Ser. 12. Vol. 5: 984-987.

Hille Ris Lambers, D. 1949. Contributions to a Monograph of Aphididae of Europe. *Temminckia* 8: 268-274.

Hottes, F. 1933. Descriptions of Aphiidae from Colorado. *Proc. Biol. Soc Wash.* 46: 19-21.

(Received April 3, 1958)

A Mobile Cage for Collecting Adult Insects in the Field[1]

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During investigations at the Charlottetown laboratory on the biologies of root maggots and their predators, an attempt was made to identify the various insect species present in rutabaga fields. Although many specimens of several species were observed around rutabaga plants, few of them were captured with ordinary sweep nets. The mobile collecting cage described herein was devised to collect large numbers of many species of insects alive and uninjured.

Construction

Fig. 1 shows the cage set up for operation. The frame is made of structural angle aluminum, that for the base being 1 by ¼ in. and that for the upper section being 1 by ⅛ in. The netting, 16-mesh plastic screen, is fastened to the frame by ¾-in. quarter-round pine that is fastened to the frame with ¾-in. brass screws. The bottom of the base is 7 ft. at the front, 5½ ft. at the back, and 4 ft. on the sides; the top of it is rectangular, 5 ft. from front to back and 5½ ft. across. The corner pieces joining the bottom and top of the base are 1 ft. long, all the joints being welded. The upper section, the front edge of which is hinged to the front of the top of the base, is 5 ft. 2 in. at the bottom, 3 ft. at the top and 5½ ft. on the sides. It is supported at the rear by two removable uprights, each 3 ft. long, that fit into slots in the top of the base. Handles are hinged to the sides of the top of the base as shown in Fig. 1. The upper section and the handles fold down upon the base when the uprights are removed from the slots.

Pieces of canvas are fastened along the bottom of the base. The lower part of the piece across the back is cut into strips 2 in. wide and 10 in. long, and a piece of lead or steel weighing about ½ oz. is fastened to the end of each strip. This piece is zippered to a narrow strip of canvas fastened to the bottom of the cage (Fig. 1), and it is removed during transportation to prevent fraying. The side and front pieces of canvas are rolled up and tied during transportation.

The wheels are standard balloon-tired bicycle wheels. The axles fit into slots in short pieces of angle aluminum brackets that are welded to the base of the cage (Fig. 2); the wheels are thus readily removed for transportation.

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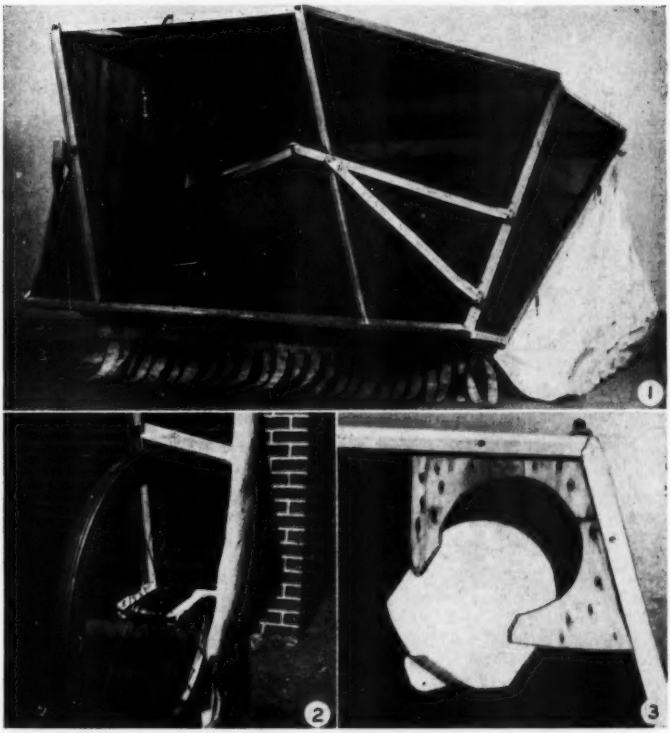

Fig. 1. Rear view of the mobile collecting cage set up for operation.
Fig. 2. Wheel and brackets on base of cage showing construction details.
Fig. 3. Opening in cage, showing construction details.

Fig. 3 shows details of construction of the opening through which insects are collected into a cylindrical transfer cage. The opening is 6 in. in diameter and the screening surrounding it is reinforced with $\frac{3}{8}$-in. plywood that is stapled and cemented to the plastic screen. The hole is closed with a flat piece of tin or light-gauge galvanized iron that fits into slots in the plywood.

The cylindrical transfer cage is 18 in. long and 8 in. in diameter, the top, base, and side strips being of $\frac{3}{8}$-inch plywood. Plastic screening is stapled and cemented to the plywood. The opening in the base of this cage is the same size and the closing mechanism is the same as those described above for the opening in the main cage.

A canvas hood is used to cover the screened area of the main cage. It is painted black on the outside.

Operation

The cage is set up as shown in Fig. 1. Sweeps are then made in a field, the back of the cage being kept as low as the height of plant foliage permits. When a sweep is completed, the front piece of canvas is unrolled to prevent escape of the insects and a black canvas hood is placed over the cage. The transfer cage is then held in position over the opening in the main cage, the pieces of tin are removed, and insects are allowed to move from the darkened main

cage up into the transfer cage. In trial sweeps with this apparatus more than 6,000 insects were captured in a rutabaga field in approximately 15 min.

The apparatus has been used mainly for capturing adults of *Hylemya brassicae* (Bouché), *H. antiqua* (Meig.), *H. liturata* (Meig.), *Coenosia tigrina* (Fall.), and *Scatophaga stercoraria* (L.), and it is much superior to ordinary sweep nets for collecting large numbers of these species alive and uninjured. For study of a particular species, collections were moved from the transfer cage to an outdoor study cage like the one described by Harcourt (1957), and specimens of the desired species were captured with a small plastic collecting device similar to that described by Lindquist (1952) and placed in a rearing cage.

Acknowledgments

The author wishes to thank Mr. F. M. Cannon, Officer in Charge, Crop Insect Section, Charlottetown, for taking photographs, and Mr. C. P. Duffy, Assistant Technician, for assistance in constructing the apparatus.

References

Harcourt, D. G. 1957. An outdoor study cage for phytophagous insects. Ann. Rept. Ent. Soc. Ontario 87 (1956): 11-14.

Lindquist, O. H. 1952. A device for capturing insects in rearing containers and cages. Can. Ent. 84: 380-381.

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The Effect of a Microsporidian Parasite of the Spruce Budworm, *Choristoneura fumiferana* (Clem.), on Two Internal Hymenopterous Parasites[1]

By H. M. Thomson[2]

Apanteles fumiferanae Vier. and *Glypta fumiferanae* (Vier.) are two well known hymenopterous parasites of the spruce budworm in Canada. While studying a microsporidian disease of the budworm caused by *Perezia fumiferanae* Thom. (Thomson, 1955) it was observed that occasionally the microsporidian and one of the hymenopterous parasites occurred together in the same host. This paper is a report of a study of the effect of the microsporidian on the hymenopterous parasites.

Methods

For some years a stand of white spruce, *Picea glauca* (Moench) Voss, in the Uxbridge County Forest in southern Ontario, has been severely infested by the spruce budworm. The budworm population is widely parasitized by the microsporidian and to a lesser extent by the two hymenopterous insects. Both insect parasites emerge as larvae from the host larva to pupate, and examination of the host larval remains by dark-field microscope revealed whether or not the host had also been parasitized by the microsporidian. In most cases the insect parasites were allowed to complete development, but a few from microsporidian-infected and non-infected hosts were fixed in alcoholic Bouin's fluid and stained with Heidenhain's haematoxylin to determine whether or not the *Apanteles* and *Glypta* larvae were also attacked by the microsporidian.

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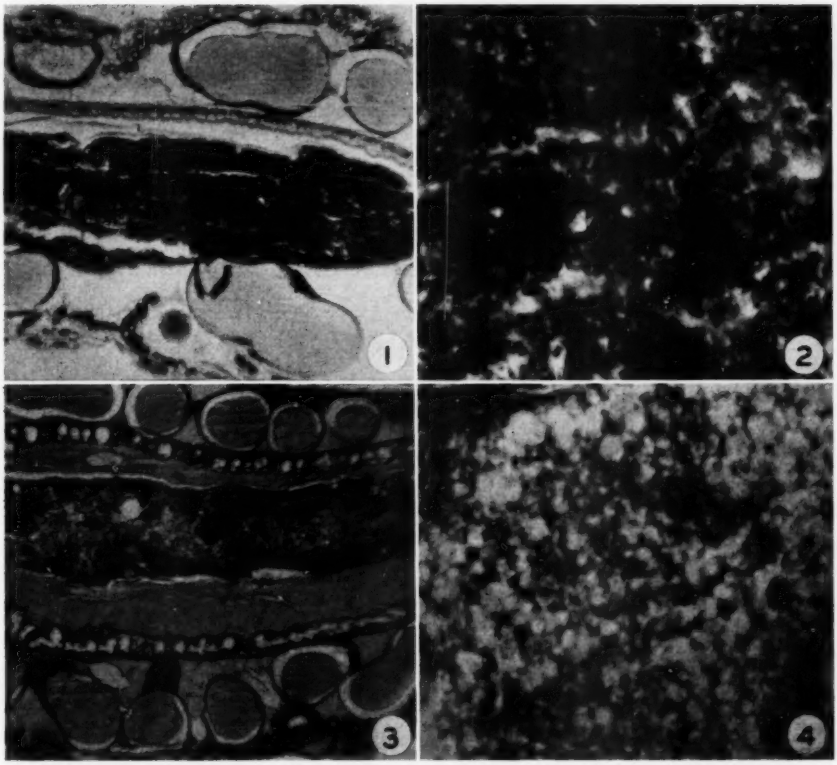

Figs. 1-4. 1. Section of *Apanteles fumiferanae* larva from heavily infected budworm larva. x 60. 2. Enlarged portion of Fig. 1 showing closely packed *P. fumiferanae* spores in gut. x 780. 3. Section of *Apanteles fumiferanae* larva from non-diseased budworm larva. x 60. 4. Enlarged portion of Fig. 3, no spores present in gut. x 780.

Results

Crushed preparations of *Apanteles* and *Glypta* larvae from infected hosts showed large numbers of microsporidian spores. Sectioned material revealed that these spores were entirely confined to the gut contents, and in no case had they invaded the tissues of the parasite larvae. (Figs 1 and 2). The numbers of spores appeared to be directly correlated with the degree of microsporidian infection of the host larva and in cases where the host infection was heavy the spores constituted almost the entire gut contents of the parasite larva. In contrast, the gut contents of parasite larvae from uninfected hosts contained only fragments of host tissues (Figs. 3 and 4). As the parasite larva has a blind gut, it would appear that all the spores ingested while feeding on infected tissue accumulate within the gut, being neither digested nor able to infect the insect parasite.

Despite the fact that the microsporidian does not invade the tissues of the larval parasite, there is evidence that it does exert an adverse influence on the ability of the parasite larva to complete pupation. Tables I and II indicate that a much higher proportion of those parasite larvae emerging from infected hosts failed to complete development than did those from uninfected hosts. A

TABLE I

Number and fate of *Apanteles fumiferanae* larvae emerging from microsporidian-infected and non-infected budworm larvae

Fate of parasite	Status of budworm host		Total
	Infected	*Non-infected*	
Pupated	7	8	15
Died	18	2	20
Total	25	10	35

$X^2 = 5.85$ $X^2.05 = 3.84$

TABLE II

Number and fate of *Glypta fumiferanae* larvae emerging from microsporidian-infected and non-infected budworm larvae

Fate of parasite	Status of budworm host		Total
	Infected	*Non-infected*	
Pupated	3	12	15
Died	5	0	5
Total	8	12	20

$X^2 = 6.93$ $X^2.01 = 6.63$

Chi-square test shows that the observed values exceed the expected values at the 5% level in the case of *Apanteles* and at the 1% level in the case of *Glypta*. It, therefore, appears that the microsporidian causes a significant mortality among the parasite larvae without directly infecting them.

Discussion

A possible explanation of the ability of the Microsporidia to cause mortality among the parasite larvae without directly infecting them may be found in the work of Grosch (1949), who presented evidence that parasite larvae of this type store food in their blind-sac midguts to last them through pupation. Thus, when almost the entire volume of the midgut is filled with inert spores, sufficient food cannot be stored and the parasite dies of starvation.

References

Grosch, D. S. 1949. The relationship of the midgut to growth and development of *Habrobracon* with a pertinent note on sporozoan infection. *J. Elisha Mitchell Sci. Soc.* 65: 61-70.

Thomson, H. M. 1955. *Perezia fumiferanae* n. sp., a new species of Microsporidia from the spruce budworm *Choristoneura fumiferana* (Clem.). *J. Parasitol.* 41: 416-423.

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